PROCEEDINGS

of the

Indiana Academy *of* Science

Founded December 29, 1885

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Volume 60
1950

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ALTON A. LINDSEY, EDITOR

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Spring Meeting
May 5-6
VERSAILLES STATE PARK

Fall Meeting
November 2-4
HANOVER COLLEGE

Published at Indianapolis, Indiana
1951

1. **Instructions for Authors** appear at end of this volume, p. 344.

2. **Exchanges.** Items sent in exchange for the Proceedings and correspondence concerning exchange arrangements should be addressed:
Indiana Academy of Science. Library
c/o State Library, Indianapolis 4, Indiana

3. **Proceedings** may be purchased through the State Library at $3.00 per volume.

4. **Reprints** of technical papers can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

5. The **Constitution** and by-laws reprinted from v. 44 and the **Membership** list reprinted from v. 56, are available to members upon application to the secretary, Wm. A. Daily, Eli Lilly Co., Indianapolis, Indiana. **Necrologies** reprinted from various volumes can be supplied relatives and friends of deceased members by the secretary.

6. **Officers** whose names and addresses are not known to correspondents may be addressed care the State Library. The address of the editor of the present volume is Dept. of Biological Sciences, Purdue University, Lafayette, Ind.

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OFFICERS AND COMMITTEES FOR 1950

OFFICERS

President, S. S. VISHER, Indiana University.
Vice-President, O. B. CHRISTY, Ball State Teachers College.
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Treasurer, W. P. MORGAN, Indiana Central College.
Editor, A. A. LINDSEY, Purdue University.
Press Secretary, P. MCGRAIN.

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Bacteriology, H. KOFFLER, Purdue University.
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Chemistry, KEITH SEYMOUR, Butler University.
Entomology, GEORGE GOULD, Purdue University.
Geology and Geography, OTIS P. STARKEY, Indiana University.
History of Science, M. G. MELLON, Purdue University.
Mathematics, WALTER H. CARNAHAN, Purdue University.
Physics, DUANE ROLLER, Wabash College.
Psychology, ROBERT BRUCE, Wabash College.
Zoology, SEARS CROWELL, Indiana University.

EXECUTIVE COMMITTEE

(Past Presidents, Current Officers, Divisional Chairmen, and Chairmen of Standing Committees)

C. A. Behrens, R. Bruce, W. H. Carnahan, O. B. Christy, R. E. Cleland, N. M. Coats, S. Crowell, W. A. Daily, J. J. Davis, C. C. Deam, E. F. Degering, H. E. Driver, W. E. Edington, H. E. Enders, R. C. Friesner, G. Gould, C. B. Heiser, T. Just, E. Kintner, H. Koffler, A. A. Lindsey, R. W. Lefler, Eli Lilly, Preston McGrain, J. F. Mackell, E. G. Mahin, C. A. Malott, M. S. Markle, R. E. Martin, K. S. Means, M. G. Mellon, H. H. Michaud, W. P. Morgan, F. Payne, C. L. Porter, R. R. Ramsey, D. Roller, K. Seymour, O. F. Starkey, S. S. Visher, F. B. Wade, F. N. Wallace, Paul Weatherwax, W. Welch, J. S. Wright, T. G. Yuncker.

BUDGET COMMITTEE

(President, Secretary, Treasurer, Editor, and Chairmen of Junior Academy, Library, Program, and Relations of Academy to State)

Chairman: S. S. Visher, Indiana University; W. A. Daily, W. P.

Morgan, A. A. Lindsey, H. Michaud, Nellie M. Coats, R. E. Martin, Frank N. Wallace.

COMMITTEES ELECTED BY THE ACADEMY

Trustees of the Academy Foundation (Term 4 years): Chairman, J. S. Wright, Eli Lilly & Co., Indianapolis (term ex. 1952); F. B. Wade (term ex. 1951). Following Dr. Wade's death, Ward J. Rice of Eli Lilly & Co. was appointed his successor.

Bonding of Trustees (elected annually): Chairman, R. C. Friesner, Butler University; Scott McCoy.

Research Grants (term 5 years): Chairman, T. G. Yuncker, DePauw University (term ex. 1949); E. G. Mahin (1952), H. H. Remmers (1950), Paul Weatherwax (1951), J. S. Wright (1953), S. S. Visher and W. A. Daily (ex officio).

COMMITTEES APPOINTED BY THE PRESIDENT

Auditing: Chairman, K. S. Means, Butler University; S. E. Elliott.

Biological Survey: Chairman, C. B. Heiser, Indiana University; F. P. Allyn, W. B. Barnes, H. J. Brodie, F. K. Daily, H. O. Deay, R. C. Freisner, S. D. Gerking, H. H Michaud, Winona Welch, Frank Young.

Fifty-Year Index: Chairman, Ray C. Friesner, Butler University; N. M. Coats, W. P. Morgan, F. N. Wallace, Paul Weatherwax.

Indiana Men of Science: Chairman, S. S. Visher, Indiana University; W. E. Edington, J. S. Wright, M. G. Mellon, Paul Weatherwax.

Junior Academy: Chairman, H. H. Michaud, Purdue University; N. E. Adams, F. R. Elliott, E. Kintner, W. P. Allyn, J. E. Potzger, R. H. Cooper, P. L. Whitaker, A. Strickler, R. E. Martin.

Indiana Science Talent Search: A sub-committee of the Junior Academy Committee—Chairman, R. W. Lefler, Purdue University; F. Payne, P. D. Edwards, W. H. Welch, L. H. Baldinger, C. L. Porter, Walter Leckrone (ex officio).

Invitations: Chairman, Edward Kintner, North Manchester College; A. H. Meyer, P. D. Edwards, J. E. Potzger.

Library: Chairman, N. M. Coats, State Library; R. C. Friesner, J. S. Wright.

Membership: Chairman, J. J. Davis, Purdue University; W. P. Allyn, Rev. C. P. P. S. Baechle, Juna Beal, H. T. Briscoe, R. M. Caldwell, J. R. Dragoo, P. D. Edwards, S. R. Esten, R. C. Friesner, Sister M. C. Fritsch, R. E. Girton, W. H. Headlee, G. F. Hennion, R. L. Hicks, G. E. Hines, L. B. Howell, B. A. Howlett, J. L. Hyatt, Alma Long, M. S. Markle, A. H. Meyer, Alvin Strickler, J. E. Switzer, W. H. Welch.

Necrologist: W. E. Edington, DePauw University.

Nominations: Winona Welch, Chairman; R. C. Friesner, F. Payne.

Program: Chairman, R. E. Martin, Hanover College; R. C. Friesner,

H. H. Michaud, C. Hire, Ned Guthrie, J. L. Hyatt, G. T. Wickwire, J. S. Wright J. E. Potzger.

Publication of the Proceedings: Chairman, A. A. Lindsey, Purdue University; R. C. Corley, P. D. Edwards, Paul Weatherwax.

Relation of Academy to State: Chairman, F. N. Wallace, State Dept. of Conservation; Daniel Den Uyl, H. J. Reed, Eli Lilly, J. S. Wright.

Representative on Council of A.A.A.S.: E. F. Degering, Illinois Institute of Technology.

Resolutions: Chairman, R. E. Cleland, Indiana University; J. F. Mackell, A. H. Meyer.

MINUTES OF THE SPRING MEETING

VERSAILLES STATE PARK

HASSMER HILL CAMP

MAY 5, 6, 1950

President Visher called the Executive Committee meeting to order at 4:30 P. M. in the Hassmer Hill Dining Hall. Twenty members were present.

The officers and committees reported as follows:

Treasurer: W. P. Morgan gave a resume for the year 1949.

Editor: A. A. Lindsey reported that the corrected galley for vol. 59 is in the hands of the printer.

Press-Secretary: Preston McGrain added "Outdoor Indiana" as an outlet for favorable publicity.

Index: The index is up to date according to R. C. Friesner.

Indiana Men of Science: S. S. Visher read the following resolution proposed by John S. Wright:

> RESOLVED, that if the committee on the preparation of the proposed directory and history of Indiana Men of Science finds it practicable to make a contract for its publication during the current year, it be empowered to act, provided that in so doing it shall not involve the Indiana Academy of Science in any expense therefor beyond amounts available in the treasury under "designated fund" contributions.

Junior Academy: H. H. Michaud reported that there are now about 30 clubs, almost double the number we had during the war period. The last Junior Assembly held in Indianapolis under the auspices of the Indianapolis Times, the Academy and Junior Academy was a success. Expenses for the Junior Academy have been about $20.00.

A committee composed of R. W. Lefler, Winona Welch, and R. C. Friesner was appointed to investigate the possibilities of using the official seal of the Academy for the Junior Academy.

Library: In the absence of Nellie Coats, R. C. Friesner reported that the shelving had been ordered for the new Academy library.

Program: R. E. Martin reported that plans were well under way for the fall meeting, and that a tentative date of the first week in November had been set.

Relation of the Academy to State: It was moved, seconded and carried that Frank N. Wallace should ask the legislature to appropriate $4,000 for the next year.

Dues: R. C. Friesner proposed an amendment which would increase the annual dues from one to two dollars beginning in 1951. This was approved.

Research Grants: T. G. Yuncker reported that the sum of 280 dollars is available for research projects.

New Business: A motion was proposed by R. C. Friesner that new members should not receive the Academy Proceedings for the previous year. This motion was tabled until the fall meeting.

The meeting adjorned at 5:45 P. M.

Dinner Meeting: Following the dinner at 6:30 P. M. an address of welcome was given by S. S. Visher.

S. W. Switzer reported 49 new applicants for membership which were duly elected.

Talks on geology and biology of the vicinity were given by Professor G. T. Wickwire and H. H. Michaud respectively. Kodachromes of the spring flowers were shown by Frank N. Wallace.

One hundred and twenty-seven attended the banquet.

On Saturday morning, May 6, three field trips were organized. These trips and leaders were:

Bird hike led by H. H. Michaud

Botany trip by J. E. Potzger

Geology trip by G. T. Wickwire.

W. A. DAILY, Secretary
Indiana Academy of Science.

MINUTES OF THE EXECUTIVE COMMITTEE

HANOVER, NOVEMBER 2, 1950

The Executive Committee of the 66th session was called to order by President Visher in Room 102, Classic Hall of Hanover College at 7:45 P. M. The minutes of the Spring Meeting, held at Versailles State Park were read and approved. The reports of officers and committee representatives were presented and accepted as follows:

Academy Trustees. In the absence of Chairman Wright, W. P. Morgan reported as follows for the year 1949-50:

Balance from the previous year	$ 532.47
Total Receipts	1,519.99
Total	$ 2,052.46
Expenditures	
Transfer to Principal from Income for investment	$ 1,250.00
Postage and insurance charge on Series D bonds	2.50
The Union Trust Co. fee, 5% of $1,519.99	76.00
Total	$ 1,328.50
Cash Balance at the Union Trust Co.	$ 723.96

Assets in the Fund as of September 30, 1950

(1) $5,000.00 U. S. Savings Bond Series G—cost	$ 5,000.00
$6,900.00 U. S. Treasury Bonds Series G—cost	6,900.00
(6) Shares Standard Oil of Indiana common stock par	150.00
Total at par or cost	$12,050.00

Treasurer. Final report of the treasurer for the year 1950:

Receipts

Balance on hand January 1, 1950	$1,955.96	
A.A.A.S. refund for research grants	100.00	
Dues and initiation fees	1,491.00	
Designated gifts	500.00	
Publications sold	23.24	
Authors' reprints Vol. No. 54	19.76	
Authors' reprints Vol. No. 56	37.34	
Authors' reprints Vol. No. 57	7.87	
Authors' reprints Vol. No. 58	288.58	
Authors' reprints Vol. No. 59	666.03	
		$5,089.78

Disbursements

1—Program Committee	$ 274.06
2—Editor Vol. No. 58	74.14
3—Editor Vol. No. 59	200.00
4—Expenses of Secretary	130.50
5—Expenses of Treasurer	129.50
6—Mailing Proceedings	119.16
7—Stationery	100.65
8—Surety Bond	62.50

9—Bookwalter Co. balance due Vol. No. 59 ...	279.45		
10—Authors' Reprints Vol. No. 59	1,253.78		
11—Jr. Academy Expenses	26.00		
12—Author Award 1950, Paul Weatherwax	25.00		
13—Author Award 1950, L. S. McClung	25.00		
14—Winona Welch research grant	50.00		
15—Duane Roller research grant	37.50		
16—Returned Checks	11.58		
17—Expenses to five officers as directed by action of 1947 Executive Committee	100.00		
18—To the preparation of the manuscript of "Indiana Scientists under direction of S. S. Visher	843.42		
		$3,742.24	
*Balance on hand		1,347.54	
			$5,089.78

*Balance includes $359.58 designated for use in the publication of "Indiana Scientists" and $50.00 designated for 1951 Author Awards.

(Signed) W. P. MORGAN
Treasurer

(Signed) KARL S. MEANS,
S. E. ELLIOTT,
Auditors.

Auditing Committee. The treasurer's report was audited and approved by the committee. The statement of the Union Trust Company as to the Society's account and holdings was checked by the trustees and the chairman of the auditing committee.

Bonding Committee. Ray C. Friesner, chairman, reported that the Academy carries with the Hartford Accident and Indemnity Company a bond in the amount of $2,000.00 for the Treasurer and $5,000.00 each for the Trustees. These are on a position basis. The bond is renewable triennially at a total cost of $62.50 for the three-year period. The next expiration date is November 18, 1950, and the bond will be renewed on or before that time unless the Academy should instruct the Committee otherwise.

Research Grant. T. G. Yuncker, chairman, reported that the committee had made a grant of $100.00 to Winona Welch, Department of Botany, DePauw University. M. G. Mellon was nominated to serve on this committee. At the request of E. G. Mahin to be released from this committee, W. H. Johnson was nominated to serve the remainder of the term.

Editor and Publication of Proceedings. Volume 59 of the Proceedings was published on September 15, 1950. The printer's bill for 1,000 cloth bound copies and 600 paper bound copies was $3,279.45. The state has allotted $3,000 for the volume.

8,615 reprints were made at a cost of $1,253.78.

A short section "Instructions for Contributors" was added at the end of the Proceedings. Reprints were made for distribution to prospective authors.

The expenses of the Editorial office totaled $176.00.

It was moved and carried that the Academy pay the difference of $279.45 between the state appropriation and the bill for Vol. 59 of the Proceedings.

Concerning the assumption of partial payment for reprints by the Academy as done in recent years, it was moved by Ray C. Friesner and carried that the Editorial Committee make a report on the matter with recommendations at the Council meeting early in 1951 and that the Council have the power to act upon it.

Press Secretary. Preston McGrain reported that notices and final programs of the fall meeting were sent to Newsweek, Industrial Laboratories and Outdoor Indiana as well as the regular newspaper outlets. Ray C. Friesner sent several copies of the program to each college and university in the state for posting. The Academy is indebted to Mr. Frank S. Baker, Director of Publicity, Hanover College, for the splendid coverage which the fall meeting received.

For the benefit of publicity, it was moved and carried that when technical abstracts are called for in the fall, popular abstracts also be requested.

Biological Survey. Little new material in the way of faunistic and floristic work has come to the attention of the committee since the last report, according to C. B. Heiser, chairman. Winona Welch has continued her researches on the mosses of Indiana, and Ray C. Friesner in the report of the State Flora Committee lists 12 new species for the state.

W. E. Ricker, who has accepted a position outside of the state, has asked to be relieved of his duties on the committee.

Ten Year Index. Ray C. Friesner reported that all but Volume 59 of the Proceedings have been indexed; however, the latter is one-half completed.

Indiana Scientists. S. S. Visher reported that the volume will probably be completed by the end of 1950.

Indiana Science Talent Search. Ralph W. Lefler, chairman, reported as follows:

"The necessity for the early identification and for the continued development of our talented in all fields of science and mathematics is being recognized by the Academy through its Science Talent Search Committee. 28 high school seniors were honored at last year's Junior Scientists Assembly and were recommended for scholarships in Indiana Colleges. Though many of these have gone outside the state, they have been awarded more than $33,000 to support their undergraduate programs of study.

The Junior Scientists Assembly will be held in the Riley Room of the Claypool Hotel in Indianapolis on March 24, 1951. Dr. H. J. Mueller, Nobel Prize Winner, Dept. of Zoology, Indiana University, will address the Assembly."

It was moved and carried that the secretary write a letter to Walter Leckrone, Editor of the Indianapolis Times, thanking him for his continued loyal support of the Junior Academy.

Junior Academy. Howard Michaud reported that there are at present thirty active clubs in the Junior Academy representing twenty-seven Indiana high schools. Four new science clubs were added during the past year including the science Club, Huntingburg; the Sci-Math Club, Attica; the future Scientists of America, Tolleston School, Gary; and the UP-N-Atom Club, Crawfordsville.

Official sanction for the Junior Academy meeting was received this year from the Activities Committee of the Association of Secondary School Principals. The need for obtaining sanction had not previously been called to our attention. The annual program of the Junior Academy has however, always conformed to the objectives, rules and regulations set forth by the committee.

The affiliation of the Junior Academy with Science Clubs of America, Washington, D. C., provides many services to the clubs that would otherwise be impossible. The sponsor handbook is an indispensable aid to club sponsors.

Most important items include suggested activities and projects, science service aids, recommended science books, and a list of free and low cost materials for science clubs. In fact, the service has proven so helpful that there are many more SCA than junior Academy clubs in the state.

The Junior Academy participated again in the national and state Science Talent Search in cooperation with Science Clubs of America and the Indianapolis Times. The state Science Talent Search Committee under the direction of Professor R. W. Lefler should be highly commended for the excellent work they are doing in the identification of science talented youth. Six of the twenty-eight state winners were Junior Academy members. Working cooperatively, as we are, it seems that more of the high schools participating in the talent searches should also be members of the Junior Academy.

The total expenditures for the Junior Academy in 1949 were $20.72. This included expenditures for printing the News-Letter in 1949 and mailing costs. This year's cost of supplies and postage to date is $21.55.

The Junior Academy has enjoyed a slow but steady progress since first organized in 1931. There are many more potential science clubs in Indiana that need just a little encouragement to become active in the work of the Academy. Members of the Junior Academy Committee, located by districts, might prove exceedingly helpful in making occasional contacts with science teachers in their areas.

Library. Chairman, Nellie M. Coats, reported that the major event has been the setting aside this year of separate stack space for the library's materials. Five-hundred and sixty linear feet of steel shelving were purchased by the State Library and installed in a separate room. Adjoining this stack area there is a small office for use of Academy officers and members.

The library continues to expand, thirty-seven new serial titles having been added this year from such institutions as the Polish Academy of Sciences and Letters, the Societé Neuchateloise des Sciences Naturelles, the Eastman Kodak Company, Escuela Agricola Pan Americana, Tegucigalpa, Honduras, and the Centre National de la Recherche Scientifique, Paris.

Thirty-three agencies previously on the exchange resumed shipments.

As usual the State Library supplied the manual labor involved in mailing the Proceedings to the members, this year sending out nine-hundred and seventy-eight copies of vol. 59 shortly before this meeting.

Membership. J. E. Switzer reporting for J. J. Davis stated that 50 applications for membership had been received to date.

Representative on Council of A.A.A.S. Ed. F. Degering sent the minutes of the Council meeting which he attended to the secretary.

Nominating. Winona Welch reported that her committee is recommending the following members for fellows: Harold J. Brodie, Indiana University; Willis H. Johnson, Wabash College; G. D. Koch, Indiana State Teacher's College; Alton A. Lindsey, Purdue University; John Seybert, Eli Lilly & Co.; Frank Welcher, Indiana University Extension.

New Business. Ray C. Friesner proposed an amendment which was approved that all new members receive the Proceedings current with the year for which they paid.

It was moved and carried that the Soil Science Society of Indiana become an affiliate of the Indiana Academy of Science.

The meeting adjourned at 10:15 P. M.

MINUTES OF THE GENERAL SESSION

Hanover College, November 3, 1950

President Albert G. Parker, Jr., of Hanover College welcomed the Academy to the Hanover campus and gave an extremely interesting talk on early Indiana scientists in the southern part of the state. The response to the welcome was given by President S. S. Visher.

The Men's Glee Club, Hanover College, rendered several delightful numbers.

The minutes of the Executive Committee were read by the secretary and approved by the Academy.

W. E. Edington presented the list of those members who had died during the year. They were: Charles F. Adams, Charles A. Behrens, Raymond K. Cassell, Benjamin D. Hitz, Clyde A. Malott, Frank B. Wade, Alfred T. Wiancko.

J. L. Hyatt, Hanover College, presented many beautiful western and local kodachromes.

J. I. Perrey, Flood Control and Water Resources Commission of Indiana, read an opportune paper on "Indiana's Growing Water Problem".

The meeting adjourned at 11:00 A. M. to meet in the various sections.

Luncheon was served in the Dining Hall of Donner Hall with 159 present.

At the annual dinner, the Hanover Harmoneers sang several appropriate numbers.

J. E. Switzer reported that there were 78 applicants for membership. These were duly elected.

Winona Welch, chairman of the nominating committee presented the following names for fellows: Harold J. Brodie, Willis H. Johnson, G. D. Koch, Alton A. Lindsey, John Seybert and Frank Welcher. These were duly elected.

The Divisional Chairmen who were elected to serve the various sections for 1951 are as follows: Anthropology, Glenn A. Black, Indiana University; Bacteriology, Edith Haynes, Indiana University Medical Center; Botany, William Gambill, Wabash College; Chemistry, R. L. Hicks, Franklin College; Entomology, James A. Clark, State Entomologist's Office; Geology & Geography, C. L. Bieber, DePauw University; History of Science, R. E. Girton, Purdue University; Mathematics, Vavaclav Hlavaty, Indiana University; Physics, Charles Hire, Indiana University; Psychology, George A. Zirkle, Hanover College; Zoology, Clarence J. Goodnight, Purdue University.

The following persons were recommended to serve as the 1951 officers: President, W. P. Morgan, Indiana Central College; Vice-Presi-

dent, J. Elmer Switzer, Bloomington, Indiana; Secretary, W. A. Daily, Eli Lilly & Co.; Treasurer, Frank Welcher, Indiana University Extension; Editor, A. A. Lindsey, Purdue University; Press Secretary, Benjamin Moulton, Butler University. This recommendation was approved and the officers unanimously elected.

Alton A. Lindsey reported for the awards committee as follows:

The fields of science selected for 1950 are bacteriology and history of science. The Charles A. Behrens prize in Bacteriology is awarded to L. S. McClung, Indiana University, for his paper entitled "Recent Developments concerning the Anaerobic Bacteria and their Activities", in volume 53 of the Proceedings. The John S. Wright prize in History of Science is awarded to Paul Weatherwax, Indiana University for his paper entitled "Early Contacts of European Science with the Indian Corn", in volume 54 of the Proceedings.

R. E. Cleland, chairman of the resolution committee read the following report:

"Whereas, the role of science in modern warfare is of such strategic importance that the welfare, or even the continued existence, of our nation may well depend to a large extent upon the conservation and proper utilization of our scientific manpower, and

Whereas, it is deemed essential, in view of this fact, to take stock of our scientific potential and to ensure a continuing supply of trained personnel, therefore

Be it resolved, that the Indiana Academy of Science commend the effort of the Federal Government, through the National Security Resources Board and the U. S. Office of Education, to build a register of scientific and technical manpower, and that the Academy request its members to cooperate to the fullest extent whenever they are called upon to assist in the formation of such a roster, and be it further,

Resolved, that the Indiana Academy of Science express its approval in principle of the proposed plan for educational deferment recently announced by General Hershey, based upon individual competence rather than field of study. We suggest that this plan be supplemented by a suitable national scholarship program which will open this opportunity to all qualified students. We further suggest that all individuals so deferred be subject, upon completion of their training, to a term of two years in the national service, either military or civilian, in the fields of their competency.

Resolved further, that the Secretary of the Academy be instructed to place copies of these resolutions in the hands of the United States Senators of Indiana.

Resolved, that it is the hope of the Indiana Academy of Science that the Bureau of the Census will publish a statistical atlas depicting in graphic form the tables to be found in the Census of 1950.

The Indiana Academy of Science desires to record its gratitude to President Parker and to the staff of Hanover College for the kind invitation to meet on this beautiful campus, and for the gracious manner in which they have contributed to the comfort and well-being of their guests. It has been a delightful experience to be the recipients of Hanover's noted hospitality and to have the privilege of visiting the well appointed and commodious new buildings in which such an excellent program is being maintained. We wish to thank the Hanover College Glee Club and the Harmoneers for their very welcome contribution. Another much appreciated feature of the meeting has been the scientific exhibit. Our best thanks go to Dr. Martin and his colleagues for their untiring efforts to make this meeting a truly notable one."

Vice-President O. B. Christy presented President S. S. Visher who delivered a scholarly paper entitled, "Indiana Scientists".

The Sixty-Sixth Annual Meeting of the Indiana Academy of Science, with 400 registrants and 124 attending the dinner, was adjourned.

W. A. DAILY, Secretary.

NECROLOGY

WILL E. EDINGTON, DePauw University

CHARLES FREDERICK ADAMS

Atherton, Missouri — Jefferson City, Missouri
April 4, 1877 — January 21, 1950

Dr. Charles Frederick Adams, who was Director of the Laboratories of the Indiana State Board of Health from 1927 to 1934 and who left Indiana to accept a similar position in his home state, Missouri, passed away on January 21, 1950. Just six months before his death he had been made acting Director of the Division of Health for Missouri.

Dr. Adams was born at Atherton, Missouri, and after completing the work offered by the public schools he entered the University of Missouri and was graduated in 1897, at the age of twenty, with the B.S. degree in Agriculture. Following his admission to the Kansas City Medical College he became an instructor, in 1899, in both that college and the Dental College, which position he held for four years, in the meantime receiving the M.D. degree in 1902, and the A.M. degree from the University of Kansas the year following. His major fields of study were entomology and pathology. He later spent the year 1904-1905 as a graduate assistant in Zoology at the University of Chicago.

In 1905 he was appointed Professor of Entomology at the University of Arkansas and three years later he became Dean of the College of Agriculture and Director of the Experimental Station. He resigned in 1913 and returned to his home at Atherton to take up farming and dairying, which occupied him for the next twelve years. He returned to Chicago in 1926 for further study and the year following he came to Indiana as Director of Laboratories of the State Board of Health.

Dr. Adams began his active career in Public Health when he was fifty years of age and he was exceptionally well prepared both by training and experience to do most effective work in that field. As an entomologist he was interested in work with mosquitoes and flies, and his studies in both agriculture and medicine made him particularly effective as a pathologist. He served as pathologist at St. Mary's Hospital in Jefferson City. His research studies were in clinical pathology, medical entomology, and taxonomy of insects.

He was a Diplomate of both the American Board of Pathology and the American Board of Preventive Medicine and Public Health. He was a Fellow of the Entomological Society and the Society of Clinical Pathology, and he held memberships in the American Association for the Advancement of Science, the American Medical Society, and a number of other societies in entomology, pathology and medicine. He was also a member of the St. Louis and Missouri Academies of Science. He

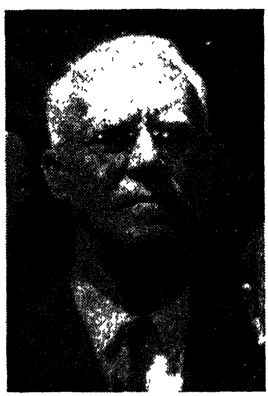
served as secretary of the Missouri Public Health Association for many years.

Dr. Adams joined the Indiana Academy of Science the same year he came to Indiana and he was made a Fellow in 1933. While, of course, distance prevented his active participation in its work, he nevertheless maintained his interest in it until his death. Dr. Adams will be remembered for his unselfish devotion to the welfare of his fellowmen and he joins that great group of public servants who have made life happier and more abundant for all.

CHARLES AUGUST BEHRENS

Grand Rapids, Michigan — Holland, Michigan
January 5, 1885 — June 22, 1950

Charles August Behrens was the first of three past presidents of the Indiana Academy of Science to pass away during 1950, and his sudden death came as a distinct shock to his Purdue associates and his numerous friends over the State. He had just completed his thirty-sixth year of service at Purdue and, following Commencement on the preceding Sunday, as was his custom, he had gone to his summer home near Holland, Michigan, where he was stricken on Thursday and passed away that night.



He was born in Grand Rapids, Michigan, January 5, 1885, both his parents being natives of Germany. Following his graduation from the Grand Rapids schools he entered the University of Michigan in 1904. He spent ten years at the University of Michigan and received the B.S. and M.S. degrees in 1909 and 1910, respectively. During the last four years he served as an instructor in bacteriology in the Medical School and also completed his work for the Ph.D. degree which was conferred upon him in 1913.

Dr. Behrens came to Purdue in 1914 as Assistant Professor of Bacteriology and was promoted the next year to Associate Professor, and in 1917 to Professor. He spent the year 1918 as a First Lieutenant, U. S. Army, in the Sanitary Corps, and was stationed at Yale University.

His principal research was done in the fields of Protozoology, Serology, Immunology and Virology, and in his last years he was much interested in the History of Science. "His work on the growth of trypanasomes pioneered research in this area of tropical medicine. He made valuable contributions to our knowledge of viruses, especially in methods of purifying and concentrating the rabic virus." He published numerous papers in various scientific journals, among them seventeen papers and eight joint papers in the *Proceedings of the Indiana Academy of Science*, the last appearing in Volume 58 for 1948.

He was a Fellow of the American Association for the Advancement of Science, and a member of the Society of American Bacteriologists and was president of its Indiana Branch in 1949. He also held membership in the Indiana Audubon Society and Sigma Xi, and he was an honorary member of the Tippecanoe County Medical Association. Dr. Behrens became a member of the Indiana Academy of Science in 1916, was made a Fellow in 1917, and was its President in 1923. During the years he had served on numerous committees of the Academy, last being Chairman of the History of Science Section for 1947 and Chairman of the Nominations Committee for Officers for 1950.

Dr. Behrens was an only child and, following the death of his father, he bestowed every care possible on his mother who in her later years became an invalid. He never married and with the death of his mother he devoted himself wholeheartedly to charitable and philanthropic work. He made contributions of collections of Victorian Furniture to the Grand Rapids Furniture Museum, and paintings to the Ryerson Library of that same city. He established Camp Anna Behrens, Michigan, on his lake property near Holland, as a memorial to his mother, and gave it to the Kent County Girl Scouts, whom he served as a counselor, and as honorary president of the Kent County Girl Scout Council.

He possessed a most charming personality with a keen, ready wit and a fund of amusing stories. He loved outdoor life and possessed the enthusiasm of a naturalist. He was a fine teacher and conveyed his own enthusiasm to his students. He believed in youth and served as a wise counselor to those who enjoyed his friendship and confidence.

In the passing of Charles August Behrens Purdue University has lost an outstanding teacher and scientist, the State has lost a fine influential citizen, and the Indiana Academy of Science has lost one of its most active, faithful and valuable members.

RAYMOND KELLEY CASSELL

Denver, Colorado	Bloomington, Indiana
January 6, 1905	July 17, 1950

It is with keen regret that one records the death of a fellow scientist who is in the height of his powers or shows promise of making a considerable contribution in his chosen field. Such a man was Raymond Kelley Cassell who was stricken with cancer and died at the early age of forty-five.

He was born in Denver, Colorado, early became an orphan, and did not receive the sympathetic guidance that allowed him to find himself until relatively late in life. After spending a period in the Army he finally entered the University of Michigan where he received the A.B. degree in 1938 and the A.M. degree in 1939. He was appointed a teaching fellow from 1940 to 1943 and then an instructor and he finally completed his work for the Ph.D. degree in geography in 1946. That fall he came to Indiana University as an instructor in geography and helped in the formulation of the initial program for the newly made Department of Geography at Indiana University. He was promoted to Assistant Professor in 1947, and despite his illness, of which he became aware two years before his death, he carried on his teaching work most successfully and was also able to do some research.

Dr. Cassell was a Fellow of the Michigan Academy of Science and he gave promise of becoming an active and valuable member of the Indiana Academy of Science. He had published research on the regional geography of Northeastern Mexico, and on the problems of industrial plant location. Also he presented a paper before the Indiana Academy of Science on "The Electric Light and Power Industry in Indiana," which was published in the *Proceedings* for 1948. During the summers of 1948 and 1949 he worked for the Bureau of Business Research for the University of Texas.

He came to Indiana University highly recommended by those who knew him best at the University of Michigan as both a fine teacher competent to teach in any branch of his chosen field and a scientist with prospects. Quiet and reserved, but courageous and determined, and thoughtful of others to the end, he left an indelible impress on his colleagues, students and friends.

BENJAMIN D. HITZ

Indianapolis, Indiana	Indianapolis, Indiana
May 20, 1890	August 14, 1949

There are a few fields of science in which the non-professional scientist may still get considerable enjoyment and frequently make valuable contributions. In the Academy, archaeology and the history of science seem to be of this type for a number of members who are active in these fields pursue them as hobbies. Benjamin D. Hitz, a prominent business man of Indianapolis, became interested in archaeology and joined the Academy in 1935 so that he could meet others who were interested in Indian lore and prehistoric mounds. And he continued his interest in the Academy and this phase of its work until his death on August 14, 1949.

Mr. Hitz was born in Indianapolis and spent his life there. He graduated from Shortridge High School in 1908 and then entered Indiana University and received the A.B. degree in 1912. Following his graduation from Indiana University he became a member of the firm of George Hitz & Co., commission merchants, serving as secretary and

treasurer until his retirement early in 1949. He was also a Director of the Fletcher Trust Company for many years.

He was active in civic affairs in Indianapolis, having served for many years on the Board of Directors of the Indianapolis Children's Museum and on the Board of the Smith Memorial Library of the Indiana Historical Society. He was a vice-president of Crown Hill Cemetery Association and served on its Board of Managers more than ten years.

Mr. Hitz was a collector of and an authority on rare books and manuscripts, and it was through his work that the Smith Memorial Library now possesses one of the finest collections of original source material on the development of the Northwest Territory and its division into states.

He served as a Captain in the Sanitary Corps, U. S. Army, in France in World War I, and after the war he wrote an account of the activity of his unit: *History of Base Hospital No. 32.*

The Academy has need of more active members of Mr. Hitz's background and interests, and it is to be regretted that Mr. Hitz was not better known to the general Academy membership.

CLYDE ARNETT MALOTT

Atlanta, Indiana — Bloomington, Indiana
September 10, 1887 — August 26, 1950

With the death of Clyde Arnett Malott the Indiana Academy of Science lost one of its most active and productive scientists. He joined the Academy in 1914 and during the years since then very few of the General Meetings of the Academy have been held at which Dr. Malott did not present one or more papers and he published a total of thirty-two papers and three joint papers in the *Proceedings*, the last appearing in 1948. His last appearance before the Academy was in 1949, and he had a paper prepared for the 1950 Meeting which was read at that meeting by Dr. McGrain, one of his former students.

Clyde A. Malott was descended from a pioneer Indiana family and was born in Hamilton County, but at the age of ten he went with his

family to Jennings County where he completed his public school education. He entered Indiana University and thereafter his career was bound up entirely with that of the University. He received the A.B. degree in 1913, the A.M. in 1915 and the Ph.D. in 1919. He became a tutor in geology at the University in 1915, was made an instructor the next year, and an Assistant Professor of Geology in 1918. Two years later he was promoted to Associate Professor and in 1924 he was made Professor of Geology, which position he held until his retirement in 1947. From 1941 to 1945 he served as acting Chairman of the Department of Geology and Geography. Dr. Malott was absent from the University when he spent the first semester of 1929-1930 as acting Professor of Geology at Williams College. He also spent several summers as geologist for several gas and oil companies, and he was consultant for the Sun Oil Company from 1938 to 1940. He served at various times on Indiana, Illinois and Oklahoma geological surveys.

He was a Fellow of the American Association for the Advancement of Science and a member of the National Speleological Society, the Geological Society of America, Sigma Xi and Phi Beta Kappa. When the honorary geological fraternity, Sigma Gamma Epsilon, was installed at Indiana University in 1926, he was its first Faculty Sponsor and he remained a Sponsor until his retirement. He was elected a Fellow in the Indiana Academy of Science in 1925, and was Vice-President in 1937 and President in 1944.

Besides his numerous publications in the *Proceedings* of the Academy, he was author of a number of other scientific papers and reports, chiefly on Indiana geology. Probably no other man knew as much about Indiana caves, underground streams and general geology as did Dr. Malott. He received the Academy prize in 1948 for the most distinguished paper in geology published in the *Proceedings* during the preceding five years. He was also author of *Physiography of Indiana*, which appeared in 1922.

Dr. Malott was an excellent and inspiring teacher and was at his best in field work. He was an authority on caverns and underground drainage, and his major interests were in physiography, stratigraphy, and petroleum geology. While not posing as a paleontologist he nevertheless took many trips hunting fossils and he was ever on the lookout for interesting specimens. His enthusiasm for field work he was able to convey to his students. The Fourth Annual Indiana Geologic Field Conference in dedicating its *Guide Book* stated: "This guide book is respectfully dedicated to Dr. Clyde A. Malott, a friend and inspiring teacher who has devoted most of his professional career to Indiana geology and has enjoyed teaching it to others."

Clyde A. Malott was distinctly an Indiana product. He loved and received his inspiration and sustenance from its hills and streams. And in turn he gave unstintedly of himself to train Indiana youth to appreciate and treasure their geologic legacies. His memory will ever be associated with the caverns and streams which he loved and taught others to love.

FRANK BERTRAM WADE

New Bedford, Massachusetts — Indianapolis, Indiana
July 8, 1875 — October 3, 1950

It is given to few high school teachers to be listed in *Who's Who in America,* but Frank Bertram Wade was no ordinary high school teacher. His vocation was chemistry and he was an excellent chemist, a recognized author of chemical textbooks, and an inspiring teacher. But it was his hobby that brought him national and international recognition for he became an authority on precious stones before he reached the age of forty-five.

Frank B. Wade was born at New Bedford, Massachusetts, on July 8, 1875. Following his graduation from New Bedford High School he was made an assistant teacher of science in the High School and he remained there until he entered Wesleyan University, in Connecticut, from which he graduated in 1901 with special honors in chemistry. That fall he went to Lewis Institute, in Chicago, as an instructor in chemistry, and in 1903 he came to Shortridge High School, in Indianapolis, as a teacher of chemistry. He was made Head of the Department of Chemistry in 1910 and he remained Head until his retirement in 1949, after forty-six years of service at Shortridge.

He was a most interesting and entertaining conversationalist with a keen wit and a ready story to illustrate his points. It was a delightful experience to hear him relate his varied experiences as a gem hunter. His hobby began when he was a Sophomore at Wesleyan when he had to miss a football game in order to take an all-day geological hike. The class that day discovered an old mine of precious stones and young Wade found a small garnet and several tourmalines which he kept through all the years. He had sought for and found precious stones in the Atlantic coastal waters, along Lake Superior, the Oregon Coast, and in San Diego County, California, as well as in Indiana creeks where some gold and stones were deposited in glacial times. He once found a fine tourmaline at the edge of a snowbank at an altitude of 11,000 feet

in Rocky Mountain National Park. He had his own home workshop where he had cut and polished hundreds of stones of all kinds except diamonds.

His first textbook, of which he was a joint author, was *Foundations of Chemistry*, which appeared in 1914, and this was followed by a *Teachers' Hand Book* in 1915, and *Laboratory Exercises in Chemistry* in 1917. His first work on precious stones, *Diamonds—A Study of the Factors that Govern their Value*, was published in 1916, and this was followed by *A Textbook on Precious Stones*, in 1917, *How to Buy Diamonds Wisely*, in 1921, and *Fundamental Facts in Regard to Industrial Diamond Setting*, in 1923. He published articles in various professional journals and was the author of thirteen papers and two memorials in the *Proceedings*, the last appearing in 1942. However, he presented papers to the Academy in 1946 and 1948 on the properties of turquoise, of which abstracts were published in the *Proceedings*. For many years he was Editor of the Chemistry Section of *School Science and Mathematics*.

He was a member of the American Chemical Society and twice president of its Indiana Section, and a member of its committee on chemical education and its Senate of Chemical Education. Long a member of the Central Association of Science and Mathematics Teachers, he was its president in 1922-1923. He was also a member of the American Association for the Advancement of Science, and Phi Beta Kappa, and a Scottish Rite Mason. He joined the Indiana Academy of Science in 1903, was made a Fellow in 1914, and was its President in 1927. He served the Academy as Press Secretary for ten years, and at the time of his death he was a Trustee of the Academy Foundation.

Just preceding his retirement from Shortridge, Saturday, March 26, 1949, was designated as Frank Wade Day and he was honored with a dinner at which Shortridge alumni, Indianapolis citizens, and representatives of various scientific organizations paid him honor.

Frank B. Wade lived a full life and a good life. He inspired and influenced thousands of Shortridge High School students. "Modest, friendly, kindly, and helpful, he has left the mark of his profession and his character on Indianapolis generations." And he was one of the most influential and highly respected members of the Indiana Academy of Science whose counsel and wisdom will be greatly missed.

ALFRED THEODOR WIANCKO

Sparrow Lake, Ontario, Canada	Eustis, Florida
October 16, 1872	December 10, 1949

Alfred Theodor Wiancko, who passed away on December 10, 1949, had served Purdue University forty years at the time of his retirement in 1943. He was born on a farm near Sparrow Lake, Ontario, and spent his boyhood and early manhood there. He entered the Ontario Agricultural College and was graduated in 1895 with the B.S. degree in Agriculture. Following several years of managing a large farm in

Minnesota, he returned in 1898 to the Ontario Agricultural College as assistant librarian and instructor in German. In 1901 he became experimentalist on the 12,000 acre farm of the Standard Cattle Company in Nebraska, and in October of that year he accepted a position at the University of Nebraska as instructor in Agriculture and Assistant Agriculturist in its Experiment Station. He came to Purdue University in 1903 as Associate Professor of Agriculture and two years later he was made Head of the newly formed Department of Soils and Crops. From 1905 to 1907 he had charge of the first instructional work at Purdue in Farm Management, Agricultural Engineering, Agricultural Chemistry, and Agricultural Botany. The Department of Soils and Crops in time became the Department of Agronomy with Professor Wiancko as Chief. He relinquished his teaching duties in 1916 and thereafter devoted his time to experimental and research work. He retired in 1943 as Professor Emeritus of Agronomy, but continued his research for a time and then went to Eustis, Florida, where he passed away.

Professor Wiancko's outstanding work was done in corn breeding, selection, and judging, and the study of soils with respect to their fertility deficiences. He began breeding and selection experiments in 1903 and by 1906 he had eighteen breeding plots over the state on farms of members of the Corn Growers Association and other interested farmers. He worked out the Indiana corn score card in 1904 and this standardized corn judging. He was judge or served on a judging committee at the State corn shows for many years. He also became a member of the corn judging committee of the international grain show in 1919 and continued until his retirement. He early discovered the wide variation in soil fertility and the necessity of studying the soil of any particular farm before giving advice as to its fertilizer needs in order to produce the best crops. The first simplified fertilizer recommendations were developed in 1918 which, in his own words, "led to a more intelligent use of fertilizer, a stepping up of the plant food content, and a great reduction in the number of analyses that cluttered the fertilizer market." In 1904 he started the systematic breeding of small grains and developed several new varieties of wheat and soy beans especially adapted to Indiana soil.

He was very thorough and careful in his work and was recognized for his high ideals and standards throughout his many years of judging. He was a fine teacher who believed that students in agriculture should have a broad general training.

Professor Wiancko was a Fellow of the American Society of Agronomy and long a member of the American Soil Survey Association, later named the American Society of Soil Science, and its president in 1922. He also held membership in the American Association for the Advancement of Science, the International Society of Soil Science, Sigma Xi, Alpha Zeta and Ceres. He joined the Indiana Academy of Science in 1909 and became a Fellow in 1935. He occasionally presented papers before the Academy.

He was the author of numerous articles in scientific journals, and

of many bulletins and pamphlets issued by the Purdue Experiment Station.

In 1942 the Indiana Corn Growers Association together with his many other friends presented his oil portrait to Purdue University. This was in recognition of the great agricultural and economic benefits derived by the State through the work of Professor Wiancko. Indeed through his great pioneering Indiana has attained renown for its agriculture and Purdue has also received world wide recognition.

PRESIDENTIAL ADDRESS

Indiana Scientists

STEPHEN S. VISHER, Indiana University

Indiana has contributed many leaders. We are widely known for our famous authors and journalists. Far less well known is the fact that Indiana has been the birthplace of a large number of scientists, a goodly number of whom have been highly distinguished. For example, two Nobel Prize Winners were born in Indiana, as were 18 members of the National Academy of Sciences and 81 starred scientists. Many other Hoosier scientists who for one reason or another have not won these particular honors, have contributed notably to science and to industry, and are widely respected.

Although every one in the Academy realizes that scientists are important—indeed precious—little research has been done on what conditions are especially conducive to the production of scientists. As a geographer, I have long been interested in where various commodities, such as wheat, hogs, coal, furniture, and works of art, are produced. Geographers are expected to know not only where all sorts of things are produced, but also why they are produced there; that is, what conditions favor their production.

It is coming to be widely recognized that man himself is civilization's most valuable resource. Though this concept is relatively new, it is surprising that so few earnest efforts have been made to learn the conditions conducive to the production of superior men. My own study of the geography of Indiana notables commenced in 1919 when I was writing the geography section of the *Handbook of Indiana Geology* for the then newly-established State Department of Conservation. I had made maps showing where in Indiana the most corn, wheat, peaches, coal, lumber, flour, furniture, etc. were produced. Then the birthplaces of a dozen famous Indiana authors were mapped, and it was seen that most of them come from less than one-fifth of the state. Two years later, a list of the Hoosier scientists starred in the 1921 edition of *American Men of Science* was compiled and their birthplaces plotted. Although their birthplaces are less concentrated in one part of the state than are those of the famous authors, most of the state had yielded few of these leading scientists.

This distribution aroused my scientific curiosity. Additional lists of Hoosier notables were gathered: college presidents, engineers, presidents of leading societies, etc. The evidence accumulating led me to expand the study to include other states. In 1928, "The Geography of American Notables" was published by Indiana University, and the volume aroused such widespread interest as to be soon out of print. During the next 20 years, further studies of notables were made, es-

pecially of distinguished scientists, and partly published in journals. That data on the starred scientists formed the nucleus of a volume published by the Johns Hopkins University Press in December, 1947.

Subsequently, additional studies of Indiana scientists were made and partly published in the "Proceedings of the Indiana Academy of Science." These and other studies of Indiana scientists will appear in a volume, *Indiana Scientists*, soon to be published by the Indiana Academy of Science, with the aid of special grants.

Indiana Scientists has four sections. The bulk of the book consists of brief biographical sketches of certain scientists who were born in Indiana, received their college or doctoral training here, or pursued scientific work here for two years or longer. Those who contributed notably to science in Indiana have fuller sketches than those merely born, college-trained, or briefly employed in the state. Most of the persons sketched are those denoted as significant Ameri scientists by appearing in one or more of the eight editions of *Amer n Men of Science* from 1906 to 1944.

Another section of *Indiana Scientists* consists of summaries by institutions of their contributions of scientists; and summaries by science of the chief contributions of Indiana scientists. These summaries, which are especially notable, are being contributed by specialists, each listed as the author of his section. It is hoped that from time to time more of this much-needed information will be contributed to the "Proceedings of the Indiana Academy of Science" and to the various journals.

A third part of the book is a series of special studies of some of the scientists. This section is partly reprinted from the "Proceedings".

The summary and conclusions make up the other chief part of the volume, which appears as Chapter 1. An abstract of that chapter comprises most of the present address.

Of the (about) 4,334 scientists sketched, slightly more than a fourth are chemists; about one-sixth biologists; nearly one-eighth physicists; and nearly an eighth engineers. In addition, there are about 250 mathematicians, 210 psychologists, 130 geologists or geographers, and almost 100 each of bacteriologists, pharmacologists, and physiologists. A score of other disciplines are represented by smaller numbers, set forth in the book.

Birthplaces of Indiana Scientists

Approximately half of the scientists sketched were born outside Indiana. Of these, 187 were foreign-born. Canada yielded 42; Germany 26, Great Britain 19, other northwestern Europe 27, eastern and souther Europe 32; China 14, other Asia 12; Africa 5; Latin America 8; New Zealand 2.

Of the American-born, New England produced 131, New York 179, Pennsylvania 156, New Jersey 34, Maryland 35, Virginia 24, and other eastern and southeastern states a total of 51.

Kentucky yielded 68 (mostly from Louisville and other points near Indiana), Tennessee and West Virginia each yielded 21, Texas 38, and

all other southern states 63. The Rocky Mountain states produced 87 and the Pacific states 65.

About half of the native Americans not born in Indiana were born in the other states of the Midwest: 299 in Illinois; 254 in Ohio; 125 in Michigan; 109 in Iowa; 75 in Wisconsin; 77 in Kansas; 64 in Missouri; 57 in Minnesota; 44 in Nebraska; and 34 in Dakota. Chicago alone yielded 94.

Of the about 2,036 born in Indiana, Indianapolis accounted for 163; five places accounted for from 40 to 55 each; six places from 20 to 27; 25 yielded seven, eight, or nine; 34 yielded five or six; 60 produced three or four; 102 places yielded two; and 257 places, one. Hence, 489 Indiana places are given as the birthplace of these scientists. Each county is credited with at least one. Many of the places of birth were small, and scores of them no longer appear on even detailed maps. Presumably, most of the 77 men and women who gave their birthplace by county only came from farms; and doubtless some who gave their birthplace as a village or town were actually born on a nearby farm.

When the number born in each Indiana county is compared with the then-existing population of the county, it is seen that some counties yielded many times as many scientists relatively as did certain other counties. Details as to which counties were exceptionally productive or sterile are in the volume.

The causes for these differences are of broad social significance. In order to illuminate them, the data must be studied deeply and from many angles. First, let us consider the cities and towns which are outstanding. Those which yielded 20 or more, arranged alphabetically with the number, are: Anderson 20, Bloomington 26, Evansville 31, Ft. Wayne 51, Indianapolis 163, Kokomo 27, Lafayette (including West Lafayette) 46, Logansport 21, Muncie 20, New Albany 20, Richmond 50, South Bend 41, and Terre Haute 55.

Places which yielded from 7 to 19 scientists are: Aurora 9, Bedford 10, Brazil 7, Brookville 7, Columbus 7, Columbia City 9, Connersville 11, Crawfordsville 14, Elkhart 13, Elwood 7, Frankfort 16, Garrett 7, Goshen 9, Greencastle 13, Greenfield 8, Hammond 8, Huntington 16, Huntingburg 10, Jeffersonville 10, Kendallville 12, LaPorte 13, Lawrenceburg 7, Lebanon 13, Liberty 8, Linton 10, Madison 14, Marion 14, Michigan City 9, Mt. Vernon 13, Newcastle 8, Noblesville 8, North Manchester 14, Peru 8, Portland 8, Princeton 8, Remington 7, Rensselaer 7, Rockport 7, Salem 12, Shelbyville 13, Tipton 7, Union City 7, Valparaiso 7, Vincennes 13, Wabash 10, and Warsaw 8.

Some smaller places which yielded fewer than 7 but were outstanding in proportion to their smaller populations are: Angola 5, Attica 5, Batesville 5, Bloomfield 5, Bluffton 6, Butler 6, Delphi 6, Economy 5, Fowler 5, Franklin 5, Goodland 5, Lagrange 5, Marshall 5, Moores Hill 5, Mulberry 4, Oakland City 4, Orleans 6, Paoli 5, Pendleton 5, Plainfield 5, Sheridan 6, Upland 5, Walkerton 5, Waynetown 4, Whitney 4, Windfall 4, Worthington 4, and Zionsville 5.

A detailed consideration of these statistics and of similar data on other groups of notables has led to the conclusion that several factors

help to explain the contrasts in yields of various places. One of these is contrasts in local educational opportunities. Many of the more productive places had academies or high schools which were recognizedly successful.

Highly significant also is the presence or absence in the community of serious-minded people. Scientists seldom come from families conspicuous for their lack of concern for the general welfare and for the future. In Indiana, the groups yielding relatively many scientists were the Quakers; people of Yankee ancestry; and those of Scotch and German ancestry. The number of German names in this book is truly astounding to a non-German such as I.

Partly because many of these scientists were the children of scientists, a few data on the number of children of these scientists may be inserted here. Of 2,595 scientists who reported being married, nearly a fourth reported no children and a fourth only one. Forty per cent had two children and 20 per cent, three. Fewer than a tenth had four or more children (55 had five, 10 had six, 4 had seven, and 4 had eight or nine.) As three children are normally required to maintain the population, more than two-thirds of these scientists are slated for biologic extinction unless their offspring have more children than they themselves reported.

The future of our country is somber if the bearing and rearing of the next generation is left largely to families poorly qualified biologically and culturally to rear children.

Of great consequence in a youth's choice of a vocation—meteorology, merchandising, teaching, or professional gambling, for example—is encouragement from one or more persons whom he deeply respects. Such encouragement may change the direction of his life. Stimulating high school and college teachers are notably significant. Specific illustrations of stimulating teachers are given in the discussion of starred scientists. Also significant is the influence of other highly-respected people in the communities. The scientist's mother may exert a profound influence. A considerable number of scientists were children of educators and scientists. The success of others from the boyhood community also has a bearing. Doubtless this influence helps to explain why certain small Indiana places yielded first one outstandingly successful scientist and later more scientists.

Highly significant in the yield of a particular place are the opportunities there for work in science. Some Indiana cities and towns have relatively many opportunities for able and earnest young people. This helps to explain the important yield of college towns, notably Lafayette and West Lafayette, where Purdue University and the United States Experimental Station operate.

Indiana Colleges and the Education of Indiana Scientists

Of these scientists many graduated from an Indiana college or university. Indiana University conferred the bachelor of arts or the bachelor of science degree on 532, Purdue on 486, DePauw on 208, Wabash on 127, Notre Dame on 108, Earlham on 95, Butler on 74, Valparaiso on 51, Indiana State Teachers (Normal) College on 46, Rose Polytechnic

Institute on 43, Manchester on 31, Hanover on 21, Franklin on 19, Indiana Central on 15, Evansville on 11, Marion on 10, Taylor and Tri-State each on 9, Ball State, Goshen and Oakland City each on 8, Moores Hill on 6, Danville on 4, Winona on 2, and St. Joseph's and St. Mary's each on 1. There were 1,924 bachelor's degrees from Indiana institutions.

Native Hoosiers comprise the bulk of the graduates of the state-supported schools. More came from outside the state to attend Purdue University than to attend Indiana University. The non-state-supported institution with the largest percentage of its alumni from other states is DePauw; the next is Notre Dame; and the third, Earlham.

Of the scientists here studied, 784 received doctorates in Indiana: 361 from Purdue, 328 from Indiana, and 95 from Notre Dame. All but a few of Notre Dame's total went to non-Hoosiers, as did most of Purdue's. By contrast, nearly two-thirds of Indiana's doctorates went to Hoosiers. Purdue and Notre Dame both conferred doctorates on many of their faculty; a large share of Notre Dame's science faculty consists of local Ph.D.'s, as does almost half of Purdue's. Indiana University, however, awarded few Ph.D.'s to its own faculty.

In the total number of their alumni sketched, Purdue and Indiana are far ahead. The institutions which have yielded most in proportion to total enrollments of men students are Wabash, DePauw, Earlham, and Indiana, in that order. Wabash, Earlham, and Indiana were especially notable before 1910. In recent years, DePauw, first, and Purdue, second, have been outstanding. But Purdue has had many more men students in recent decades than has any other Indiana school—nearly twice as many as Indiana University has had. As *Indiana Scientists* sketches many engineers and agriculturalists, as well as the more conventional types of scientists, Purdue's alumni appear in numbers. Indeed, nearly a quarter of the scientists sketched are Purdue alumni or one-time faculty members.

In tabulating the place of college training of these scientists, it was interesting to note what a large fraction graduated near their birthplace. This illustrates again the importance of nearby colleges to a community's yield. The local reputations of Wabash and DePauw appear to have been especially good, as relatively few natives of their localities graduated elsewhere. In contrast, most of the 50 born in Richmond graduated outside of Indiana as did many of the 163 born in Indianapolis. A considerable number from Lafayette and West Lafayette graduated at Indiana University, and several from Bloomington graduated at Purdue.

One of the characteristics of embryo scientists is that they are observing and earnestly seek better conditions. These traits tend to encourage them to attend colleges whose shortcomings are less evident to them than are those of their local colleges.

Indiana Places of Employment of Scientists

The number of scientists depends to no small degree upon the number who can make a living as scientists. Many people who are not scientists have much curiosity and desire to discover new truth. Many

also possess two other qualities needed: initiative and perserverance. Some of these might have become scientists if favorable conditions had prevailed. Consequently, the opportunities afforded able young scientists is highly significant.

Indiana has been the birthplace and the place of college education of many more scientists than the number to which it has afforded adequate opportunities in science to earn a living. Consequently, many of our scientists have had to enter non-scientific endeavors—largely teaching—or go to other states for employment.

A tabulation was made of the type and place of employment of those employed in Indiana. Indiana educational institutions employed 1,528 and Indiana industry 853. Indiana industrial firms have employed a sharply increasing number. For example, a competent elderly Indiana scientist believes that in 1895 fewer than 25 scientists were thus employed in contrast to several hundreds in 1950.

Purdue University has been the leader by a wide margin in the number which it has at one time or another employed: a total of 631. Indiana University has employed not many more than half that number, 350. Notre Dame has employed 111, DePauw 59, Wabash 54, Butler 45, Earlham 41, Rose Polytechnic 33, Valparaiso 33, Indiana State Teachers 27, Ball State 20, Evansville 19, Franklin 16, Hanover 11, Indiana Central 11, Manchester 10, Taylor 10, Marion 9, Vincennes 8, and Goshen 7. Employing 4 or 5 each were Oakland City, St. Mary's-in-the-Woods, Tri-State and Danville.

Purdue's outstanding leadership in the number of Indiana scientists employed reflects at least three conditions. One is the aforementioned many opportunities for scientists in the United States Experimental Station there and in part-time teaching in the University, one of the largest in agriculture and engineering. A second is that master's degrees or doctorates furnished part of the compensation to many of these scientists. A third explanation of the large Purdue total is the fact that many remained for only a short time, perhaps no more than the two years minimum necessary for listing in this book. Purdue has employed briefly numerous subsequently well-known scientists. Some of the faculty have remained for many years, but on the average the annual turn-over has been relatively large. This is also true for Notre Dame and Valparaiso. Purdue's record of attracting professors from other Indiana institutions is notable.

Although Purdue has led by a wide margin in the number of scientists employed, Indiana University has led in the distinction of some of its faculty. Consistently since starring commenced in 1906, Indiana University has had most of the starred scientists in the state, generally over two-thirds of the state total. It has also had the only members of the National Academy of Sciences. Members of its faculty who have risen high in the scientific world after leaving are also far more numerous than for the other schools.

Among industrial firms in Indiana, two have been outstanding in employment of the scientists sketched. The Standard Oil Company of

Indiana has employed 173, and Eli Lilly and Company 110. Both of these have employed many experts who have contributed notably to the advancement of science. Indeed, each has had a few starred scientists. A large majority of the Standard Oil scientists were from other states, as were somewhat more than half of those of Eli Lilly. But both have also employed many Indiana scientists, especially Ph.D.'s. (A total of 228 Ph.D.'s from the University of Chicago are sketched in this volume. Most of them have been employed by Standard Oil (Ind.), Eli Lilly, Purdue or Indiana University.)

The third Indiana corporation in the number of Indiana scientists employed is Commercial Solvents Company of Terre Haute, with 50. Concerns which have employed about a dozen are General Electric (all Ind. plants), Meade-Johnson (Evansville), Servel (Evansville), Pitman-Moore (Indianapolis), and Schenley (Aurora). Companies which have employed seven to nine are Bendix (South Bend), Magnavox (Ft. Wayne), Miles (Elkhart), Sinclair, and three Indianapolis firms, Presto-Lite, Reilly Tar, and Swan-Myers. Concerns employing four or five of these scientists are Diamond Saw, Central Soya, Glidden, Grasselli, Linde, Seagrams', Studebaker, Van Camp, Universal Atlas Cement, and U. S. Rubber (Ind.).

Some Conclusions

Indiana has been the birthplace, place of higher training, or place of employment of numerous scientists, including some of the nation's most-honored. Some 485 Indiana cities, towns, and hamlets are given by these scientists as their birthplaces, and each Indiana county has been the birthplace of one or more. Some areas have, in proportion to their population at about the time of birth of the scientists, yielded exceptionally large numbers.

Contrasts in the yield of this valuable resource, scientific leadership, are of such profound social significance that prolonged, detailed studies of their causes not only are justified but are highly desirable. The present study supplements, extends, and supports other studies and conclusions. Four of these conclusions may be summarized here.

(1) Encouragement or stimulation is deeply significant in the production of leaders. Indeed, although some business men and a few others have bragged that they were "self-made," the evidence clearly indicates that no scientists are self-made. Encouragement is essential to the development of a scientist. This encouragement may come from one or more sources. If it comes from the immediate family, that is a great help. Some receive it from an especially stimulating high school teacher or college professor. Many scientists have acknowledged that encouragement from their mother was especially significant in their earlier years, while a college teacher played a major role in their specialization and in their later career. Sometimes the stimulus comes from a friend or from a cousin, aunt or uncle. The proven great significance of encouragement justifies each of us to be generous in encouraging our own more promising students and young friends. A few appreciative words may alter their life!

(2) A second major influence facilitating the production of scientists is the presence of opportunity to obtain adequate training—and this presupposes the opportunity to obtain the benefits of studies made by previous workers in the field. The presence in Indiana of several excellent educational institutions is therefore highly significant. Since the most effective form of education is working individually with an able, enthusiastic specialist—not mere 'book learning' or mass lectures—the type of instructor available is of vital import. All interested in increasing the number of scientists should constantly remember that individual instruction of a high order is almost essential.

(3) As nearly all scientists must earn a living, the opportunity to do so is essential. Employment close at hand is of great assistance, especially to beginners. It is evident that in the present world there is great need for more scientists and for greater scientific achievement in diverse fields. Hence, scientists should be more adequately recognized and should be afforded better opportunities for their work, which, in nearly all instances, is for the benefit of mankind and not for their personal gain. It is a reflection on the good name of Indiana that we have afforded good living opportunities for so few scientists, except perchance indirectly, as teachers.

(4) Most fundamental in the yield of scientists is the presence of a favorable biologic and cultural background. An ever-increasing mass of evidence indicates that leaders in science come from families well above average in ability, earnestness, vigor and ambition. Some productive families are found in unexpected places, often because the mother, the most significant parent biologically and culturally, married out of her cultural group. However, families which yield leaders are most numerous in favored communities; for example, college towns, county seats, and attractive suburbs of cities. Such families are also relatively numerous in certain occupational groups, especially in the professional class and particularly among educators and the clergy. Productive families are also more numerous in some human stocks than in others, including, in Indiana, the Quakers, the Scotch, the Yankees, and the early Germans. Wherever they are, it is evident that families biologically and culturally distinctly above average have an opportunity to contribute more than their proportionate share of leaders, and should be strongly encouraged to make earnest efforts to do so.

The deductions just mentioned are not merely academic. Each of us here can aid somewhat. Let us resolve to do better than we have hitherto done with respect to encouraging potential scientists, partly by giving them more individual attention, and partly by increasing their opportunities to earn a living in science. Last, but not least, we should all endeavor to increase the number of children born into families qualified to produce future scientists.

ANTHROPOLOGY

Chairman: H. E. DRIVER, Indiana University

Glenn A. Black, Indiana University, was elected chairman for 1951.

ABSTRACTS

Superstitions of students at Indiana University, 1950. HAROLD E. DRIVER, Indiana University. With the help of the members of a class in primitive religion, a list of 33 superstitions was compiled and circulated in the form of a questionnaire to 172 students chosen at random from among acquaintances of members of the class. Positive responses ranged all the way from none to the query "Do you carry a buckeye?" to 58% to the item "Do you wish on a wish-bone?" The number of positive responses for individual students ranged from 1 to 24. There can be no doubt that superstitions are a reality among university students today.

The influence of political organization on the legal procedures of primitive groups. ANN SCHUTZEL, Indiana University.—This paper is a brief sketch of the Yurok and Cheyenne governments illustrating the contrast between an American Indian tribe which possesses no recognized political structure and a tribe where the organization has reached a fair degree of development, the type of social control identified with the structure, and the legal procedures followed to maintain the social euphoria.

Morpheme classes and sub-classes in American Indian languages. C. F. VOEGELIN, Indiana University.—The preface to this paper presents an argument that grammatical category may be classified as covert culture. After the preface three models of American Indian languages are presented, each with specific exemplification according to whether the languages exhibit four, three, or two major morpheme classes. It is found that the more interesting and immediate grammatical categories can be ascribed to sub-classes rather than to the major morpheme classes.

Chicomecoatl's corn. PAUL WEATHERWAX, Indiana University.—In various places in southern Mexico and Guatemala there are now grown by the Indians varieties of corn the ears of which are normally branched into two or three parts. These twin- or triple-branched ears resemble the conventionalized symbol of Chicomecoatl, an ancient Aztec corn goddess. This opens the way to speculation as to their origin.

The Fifield Site (Porter v37), Upper Mississippi Manifestations in Porter County, Indiana[1]

ROBERT R. SKINNER, Indiana University

The Fifield Site (1), a Northern Indiana Village, is in the north-central part of Porter County (Liberty Township) situated on a pleasant little bluff overlooking the swampy valley of Damon Run Creek. Interested persons will be taken to the site by the writer who lives nearby. The soil is a light sandy loam which in Section A (sections explained later) is farmed yearly but which is much less fertile in Section B. Though the site has not been surveyed it appears to cover at least twenty acres, a small portion of which is wooded. The grassy strath below, and extending far east and west, appears, itself, to have been a fairly good small game ground.

The site exists amid Woodland surroundings. These affiliations, especially Hopewell, were established in 1930 by McAllister on the basis of mound explorations made in his survey for the State Historical Bureau. No villages proper were examined, either because there are none other than the Fifield Site, or, like it, they were missed completely by the surey party (2). These Hopewellian surroundings in the northern and southern sections of the county are, of course, alienated to the Fifield Site, which upon superficial examination can be seen to be Mississippian, and with more detailed study, as will be shown, can be placed into the Fisher Focus, Fort Ancient Aspect, Upper Mississippi Phase.

The site was divided into Sections A and B physically because of a bit of erosion between the sections, and culturally because of the majority of Woodland tendencies on the A side. Though the surface collections generally paralleled the later pit findings as to pottery types, form and decoration, it became apparent that in Section A twice as much Type II pottery, the coarse, crumbly, thick, grit-tempered ware, was to be found as in Section B. Besides this, in Section A nine notched projectile points were found, while the only form to be seen in B is the triangular (Fig. 1, A, B). This is perhaps flimsy evidence, and if it weren't for the fact that Type II pottery appears in the pits of Section B mixed with Type I, the typical Fifield ware, the exceedingly small amount of Type II might be ignored as a negligible coincidence.

After the surface collections were made, a promising spot in Section B was chosen and two plots of three five-foot squares each were laid out beside each other. When the humus was removed four pits were revealed, two in each plot. Carrying the plots down to the exhaustion

[1] Glenn A. Black, Angel Mounds, showed very helpful interest when the material was being studied at I. U.; W. R. Adams, Bloomington, identified all the bones; Bob Forth, Bloomington, made the photos, and assistance in making the excavations was given by Paul Humphreys, S. Rand, and R. Cooper, all of the Calumet Region. Mr. Don F. Boyd, Dir. Sauk Trails Boy Scout Camp, revealed the site and was otherwise helpful.

FIG. 1

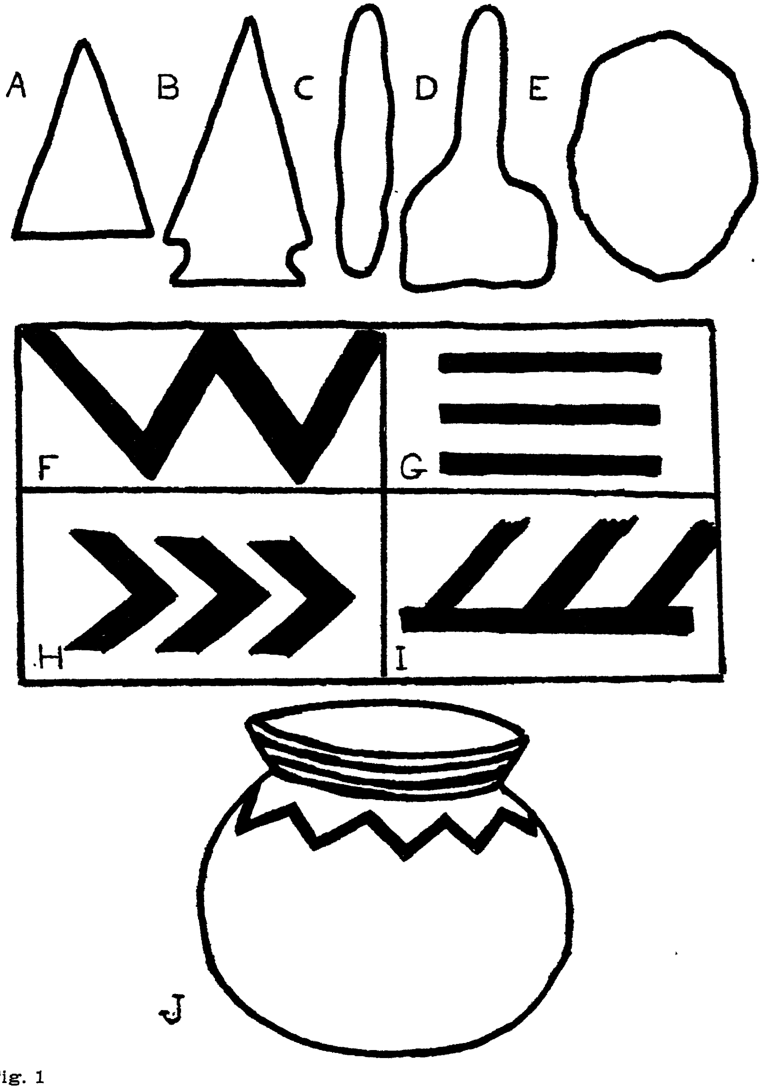


Fig. 1

Top: Flint tool forms. A, typical projectile point; B, a second type found in Section A; C and D, drill types; E, blank or scraper.

Middle: F, G, H, I, some trailing designs. G, found mostly on necks; I, often suggested in some form but never in suitable detail.

Bottom: J, assumption of use put to F (middle) and illustration of G.

of these pits constituted the entire amount of excavation. Although comparatively much was procured, it is evident that the findings listed

here are only beginnings and suggestions, and that future explorations will prove more interesting and rewarding, should they be corroborative or corrective.

Before discussing the contents a word might be said of the basin-shaped pits themselves. Were they cooking, storage, or refuse pits? Pits I and II at six inches (the humus, a six to nine inch plowline, is never considered as a level) were discovered to be one pit, though a division on the basis of content could still be discerned. One side was fire-burnt on the bottom and the profuse animal bones, mixed with a dense almost greasy humus among which were unidentifiable vegetal remains and charred nutshells, were almost invariably burnt, sometimes very charred and calcined. The other side contained clean though badly broken bones in a lighter, sandier matrix. Also in the darker burnt side was found a raccoon penis bone which is considered by some to have been used to fish things out of cooking pots. Much refuse was found throughout both sides. This was true also of the other two pits. Pit III seemed to be definitely divided, especially in the lowest level, into a cooking pit and an unfired "refuse-storage" pit similar to pits I-II. In the unfired section of III the bones were still white and generally more complete. Pit IV gave no such hints, the entire matrix being a greasy black, with large bones mixed promiscuously with charcoal, shell, pottery, and projectile points to a depth of only six inches below plowline. In this pit was a post-hole-like outline six inches in diameter which extended over a foot perpendicularly below the pit bottom, possibly to hold the pot over the fire. This was the only feature even likely to be a post-hole. The pits were from three to five feet in diameter at Level I and except for pit IV were around two feet deep counting the humus.

There were profuse faunal remains found in the four pits with some rather interesting specimens in addition to the more common material. Of course deer bones comprised the major amount of the mass and next in line of prevalence were dog, box turtle, and snapping turtle, though these were not plentiful. In Pit IV large bones of what is probably wapiti, but may be cow, were found. Bison is apparently present and good examples of wild turkey, a species of waterfowl, wolf, bear, striped skunk, raccoon, oppossum, mountain lion, bobcat, muskrat, beaver, fox and gray squirrel, and species of fish were turned up. The passenger pigeon, which, according to W. R. Adams of Bloomington, is enigmatically rare in mid-west aboriginal villages, appeared in all the pits but IV. Most puzzling is the presence of a domestic chicken humerus in Pit IV. Pit IV, however, is the shallow pit and the excavation showed that it still merged without dichotomy into the humus, possibly allowing for a later introduction of the bone.

Bone, shell, and stone tools and artifacts were found in the pits in addition to pottery. The projectile points are small, finely chipped triangles of flint; these appeared in great numbers both on the surface and in the pits, but in no pits were any notched forms found. Also of flint are two types of drill, a small nail-like form and a larger T-shaped variety. The blank or scraper is present, though not in profusion (Fig. 1,

A, B, C, D, and E). A comb or hairspreader with depressions drilled around the edges (Fig. 2, S), a notched rasper-like artifact, a beamer, a flat needle, and an unfinished whistle were of bone. A sharpened antler tine and one small cylinder of antler were found. In addition, a notched shell spoon, and a tiny bead of the same material were encountered. The discovery of a split beaver incisor with scratched incisions across the front enamel was of interest; the reason for the incisions is not known.

Of eight-hundred cord-roughened and smooth body sherds from the pits, the cord-roughened sherds outnumbered the smooth four times; .025% of these were of Type II ware, three-quarters coming from Pit IV. The Type II ware was decorated only in one instance, there by lug.

Whenever there was enough of a sherd to indicate the shape of the vessel, it was the flared bowl (olla) form. The handles are small loops on the neck but not connecting the neck and shoulder as in the Fisher prototype. A fortunate find was an almost complete example of this type from the middle level of Pit III (Fig. 3).

The principal means of decoration aside from ordinary cord-roughening is trailing, and notching of rims (Fig. 2). The trailing is divided between (1) a medium to narrow "antler-point" groove and ordinary narrow trailing, and (2) a broad, shallow type which dictates slightly the shape of the vessel, modeling having been involved in executing it, resulting in a rippled effect (Fig. 3). Therefore it is probably not actual trailing but an advancement thereon. It seems to consist generally of rows of parallel vertical canals or wide grooves around the shoulders of the pots; trailing proper, be it antler-point or otherwise, follows (with only one exception) angular rectilinear designs about the necks, shoulders, and bodies of the bowls (Fig. 2, E, F, G, H, I, M, N, P). There was usually not enough of the design to tell what motif was intended but the general idea, or one idea, seems to be similar to that found at Fisher and shown in drawing here. Lines often joined one main line at similar angles; here again the sherds were too small to show the intentions of the potter. (Fig. 1. F, G, H, I, J).

Only cord-roughened parts or pots were decorated in the above ways.

Of forty-six rim-sherds all but five were notched in one of two ways, that is, (1) plain notching on the top, outer, inner, or both sides of the orifice, or (2) incising in like manner (Fig. 2, A, B, C, I, K, M, N, P, R, T). The majority was of common notching by impressing a rounded stick on the flattened lip. Only a few notched rims were of smooth collars—decoration of any kind seems to be subsequent to cord-roughening. One rim was punctuated on the flattened lip (Fig. 2, O).

There were perhaps two instances of incising, suggesting a chevron development (Fig. 2, N), but the boundary between incising and narrow trailing is obscure. There is one sherd with a scratched cross. Rare cases of thumb depressions and four reliable examples of punctate, two from Section A and two from B, including the rim mentioned above.

were turned up. The practical absence of punctate is puzzling. Lugs or knobs appeared on five sherds, these probably non-functional, both welded and pinched little protruberances near the orifices (Fig. 2, A, D, O). Several other odd features were noted but minutiae can be omitted because of the lack of sufficient numbers to permit classification and generalization.

Considering the above with what is diagnostic of Fisher Focus it becomes apparent that the Fifield Site comes under that division

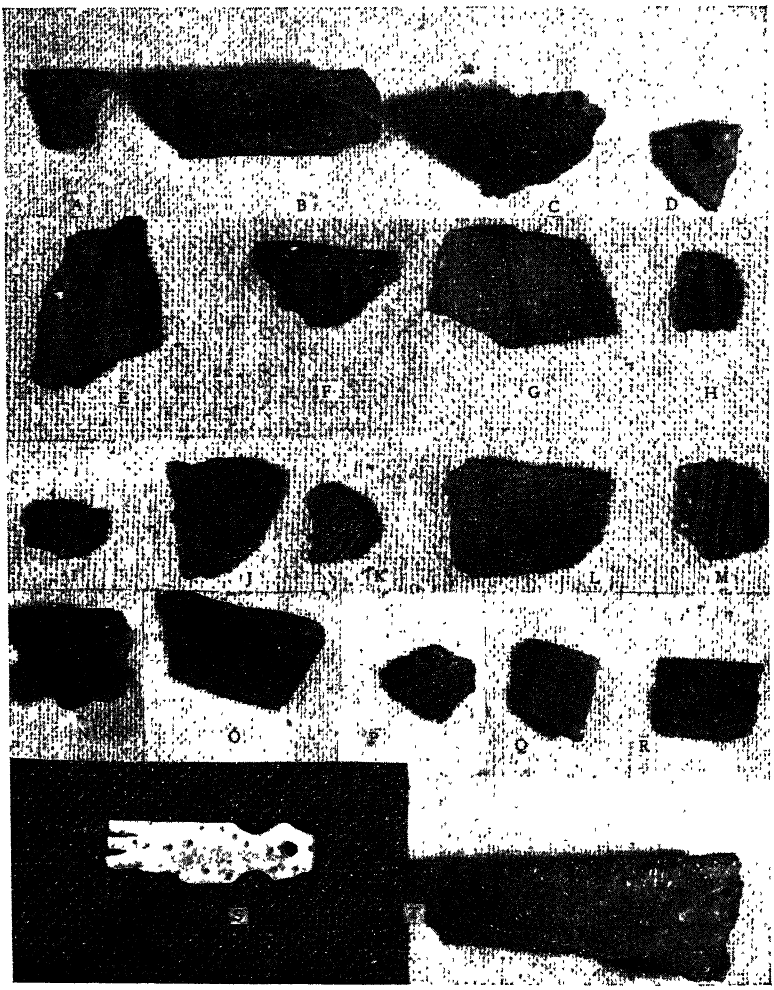


Fig. 2.

Rims and body sherds illustrating decoration techniques.

S, a broken comb converted into an ornament; T, drilled rim, for repair purposes?

most conveniently. The shell-tempered pottery of consistent bowl (olla) form chiefly decorated by trailing, rarely with loop handles on opposite sides of the rim; the fine little triangular points; the shell spoon; the whistle; the antler cylinder; and the bone beamer are things which might be found right on the Fisher Mounds Site (1).

But it finally must be admitted that there are a few problems. It can be said that the things that Fifield lacks, such as punctate pottery, beads, ear spools, gastropod ornaments, shell pendents, the various awls, and antler projectile points will probably appear in future investigations; and it must be remembered that much of the material from Fisher Mounds can be considered actual grave goods, while the Fifield material is utilitarian trash. But the Fifield village also has

Fig. 3.

Almost complete bowl (olla), sole Fifield vessel form; it illustrates most of the diagnostics.

some things which are unknown to Fisher. The drilled hair-spreader is similar to a Madisonville type. The bone rasper is reminiscent of some Feurt forms; and the bead is not a Fisher type. Also, the Fisher people apparently did not eat Bison or passenger pigeon though this does not seem to be of much importance.

Aside from these things there are further questions. Pit IV's chicken humerus is one and the two pottery wares poses another. If we are to say that the Fifield people made two types of pottery why isn't a considerable amount of the second kind shown? Likewise it does not seem likely that a few sherds might have been brought in by outsiders and strewn here and there for no particular reason. We can look to future investigations to add to our knowledge about this site and how it is related to other Fort Ancient foci.

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2. MCALLISTER, J. GILBERT. 1932. The archaeology of Porter County. Indiana History Bulletin 10, No. 1:62-66.

BACTERIOLOGY[1]

Chairman: H. KOFFLER, Purdue University

Edith Haynes, Indiana University Medical Center, was elected chairman for 1951.

ABSTRACTS

Dr. Charles A. Behrens (1885-1950). P. A. TETRAULT, Purdue University, Lafayette.—This paper consists of a memorial to Dr. Behrens.

The effect of nutritional and environmental conditions upon the aerobic and anaerobic glucose metabolism of *Bacillus subtilis* (Marburg). N. D. GARY and R. C. BARD, Indiana University.—The Marburg strain of *Bacillus subtilis* has been recognized as an obligately aerobic organism apparently lacking an anaerobic mechanism of carbohydrate dissimilation. It was found however, that growth in complex media (e. g., tryptone-yeast extract-phosphate-glucose) yielded cells which carried out a lactic fermentation under anaerobic conditions. Cells harvested from simple media (e. g., inorganic N-glucose-phosphate-0.01 per cent yeast extract) were found to have almost no glucolytic activity under anaerobic conditions but engaged in complete glucose oxidation under aerobic conditions. The cells grown in the complex media, however, exhibited only partial oxidation of glucose, the overall oxidative rate also being reduced. The factors necessary for the cultivation of cells capable of engaging in glucolysis include amino acid supplementations to the simple medium as well as the extent of aeration during growth. Addition of the B-vitamins to the growth medium did not enhance glucolytic activity. Thus, under these conditions it appears possible to determine the nutritional requirements for the specific enzymatic reactions involved in glucolysis by this organism, a mechanism as yet undescribed in *Bacillus subtilis.*

The cultivation of bacteria in chick embryos with special reference to *Brucella*. KATHLEEN GAY and S. R. DAMON, Indiana State Board of Health.—A brief history of the envolvement of the chick embryo into a valuable medium for the cultivation and study of bacteria is presented. Currently, embryo technics are finding particularly wide-spread application in the study of chemotherapeutic activity and of the pathology and infectivity of bacteria. However, their use in a public health diagnostic laboratory for the primary isolation of bacteria has not developed as rapidly. At the Indiana State Board of Health Laboratories preliminary observations indicated that young embryos might well be used for the recovery of *Brucella* from the blood stream, since it was found that

[1] The 1950 program of the Bacteriology Division is dedicated to the memory of Dr. Charles A. Behrens.

when clotted blood containing any one of the three species of *Brucella* was macerated and inoculated via the yolk sacs into 3-5 day embryos, the organisms multiplied rapidly. Subsequently, a method which it is believed can be used with comparable success in any similar laboratory developed and is being evaluated. Fifteen isolations have already been made from clotted blood inoculated into the yolk sacs of embryonating eggs.

Some aspects of fungicidal testing of quaternary ammonium compounds. HELEN M. KETCHUM and L. B. SCHWEIGER, Miles Research Laboratories, Elkhart.—A review of the literature on fungicidal tests reveals the fact that few tests are applicable for testing a fungicide under practical conditions for use. This is especially true with fungicides containing quaternary ammonium compounds.

Various methods and modifications are described. The difficulties of fungicidal testing are discussed with particular reference to the activity of formulae containing quaternary ammonium compounds on dermtophytes. A modification of the Burlingame-Reddish technic in our hands gave the most satisfactory results for routine testing and evaluating this type of fungicide.

Production and assay of experimental rabies antiserum. H. M. POWELL and C. G. CULBERTSON, Lilly Research Laboratories, Indianapolis.—In the March 24, 1950, issue of Public Health Reports we have shown that fixed rabies virus can be propagated fairly successfully in substantial titer in embryonated duck eggs.

Using duck embryo rabies virus as an antigen, we have prepared about eight liters of immune serum in rabbits. We have administered this antigen at first intravenously and later in the course of immunization by intraperitoneal injections. Rabbits are kept on a schedule of immunization and bleeding as long as possible instead of being sacrificed early.

The antiserum obtained has a virus neutralization index of 5 or 6. Concentrated serum has a higher titer which can best be measured by testing various dilutions of serum against a constant dilution of virus rather than by the index method.

Rabies antiserum prepared in this way has substantial therapeutic action against rabies street virus.

Correlation between Structure and Function of Certain Selective Toxins[1]

E. CAMPAIGNE, Indiana University

Although the term "selective toxin" has only recently come into use, the concept embodied in this phrase is an old one, originally presented by Ehrlich. Ehrlich assumed that organisms possessed a whole series of different "chemoreceptors", and that it was only necessary to discover among these one specific "chemoreceptor" in the parasite which had no analog in the organs of the host, to have the possibility of a chemical poison which would attack the parasite but not the host. He used this concept to explain the existence of antibodies, the naturally-occurring "magic bullets", and presented the same idea in the old "lock and key" theory. The "lock" is the specific chemoreceptor which was fitted by the "key", which might be drug or antibody.

These same concepts have been used repeatedly in the development of modern theory of drug action. For example, such terms as "specific enzyme inhibitor" and "antimetabolite" are merely efforts to locate more exactly Ehrlich's "chemoreceptor". We can broadly define a "selective toxin", then, as a substance which preferentially inhibits the growth of or destroys one type of organisms in the presence of other organisms or tissues.

Dr. Koffler, in planning this symposium, has posed the question: "If the postulates of comparative biochemistry are true, and all living things utilize essentially the same reactions in their processes, how is selective antibiosis possible?" The answer to this question lies in the word "essentially". This recognizes the idea that various organisms may use similar, but not necessarily identical, mechanisms in their metabolism. The problem posed for the chemotherapist is to discover and differentiate between the minor differences in the metabolism of invading organisms and host. Indeed the entire development of chemotherapy has depended on man's ability to make finer and finer differentiations in the metabolism of various organisms. The earliest clearly defined example of such differentiation probably occur in the 18th century, when the juice of the male fern was used to treat hook-worm disease. The clearly visible excretion of the worms in the feces showed the effective differentiation between host and parasite. The next significant development was Ehrlich's use of dyes and arsenicals on protozoan infections, between 1900 and 1910. The sulfa drugs, developed between 1932 and 1936, provided a tool for distinguishing bacteria from host tissues. It has been much more difficult to discriminate between viruses and host tissues, but some success has been experienced recently with certain

[1] Contribution No. 502 from the Chemical Laboratories of Indiana University. This paper was presented as part of a Symposium on Selective Toxicity.

antibiotics, including the synthetic chloromycetin. The supreme challenge lies in cancer tissues, which is actually host tissue gone wild, but certainly the differences between the metabolism of the cancer cells and the normal cells will be detectable by the proper chemical tool.

The nature of Ehrlich's "chemoreceptor" has intrigued many research workers, and led to a number of theories. One of the most productive has been that elaborated by Woods and Fildes (12) based on Fildes' observations on the relationship between growth factors and essential metabolites (3). According to Fildes, "essential metabolites" are substances formed in each stage of a synthesis necessary for growth. A "growth factor" is an essential metabolite which cannot be synthesized by the organism. An antibacterial substance functions by interfering with essential metabolites.

This interference may occur in at least two ways, either by blocking a reactive group, or by competitive inhibition. In simple terms, competitive inhibition is the displacement of an essential metabolite from a reaction by an "inhibitor". The laws of mass action apply, and relatively large amounts of drug (inhibitor) are required and this high concentration must be maintained by continued high dosage. A simple analogy exists in the "common ion" effect. One liter of 0.1 N acetic acid contains approximately 0.001 equivalents of H^+. If an equivalent amount (0.1 mole) of acetate ion is added to this solution, the $[H^+]$ is decreased one hundred fold, to 10^{-5} equivalents; to decrease the $[H^+]$ further requires much more acetate ion, however. A ten-fold excess (1.0 moles) is required to reduce the $[H^+]$ to 10^{-6}, and one hundred fold, (10 moles) to reduce it to 10^{-7}. If one imagines that the hydrogen ion is an essential metabolite, required in a minimum concentration of 10^{-6}, then more than 10 times as much acetate ion must be added as an inhibitor.

A number of examples are available for this kind of action. The classic one is that of p-aminobenzoic acid and sulfanilamide. Strauss, Lowell, and Finland (10) demonstrated that the ratio of the concentration of P. A. B. required to cause reversal of bacteriostatic action of sulfanilamide, sulfapyridine or sulfathiazole, to the concentration of the sulfa drug was constant, thus proving the law of mass action applied. Similar relationships have been proven in many other cases of bacteriostatic compounds, and have been suggested in many more.

The second interference with an essential metabolite is by blocking, or "masking" of prosthetic groups. Drugs which act in this way have the following characteristics:

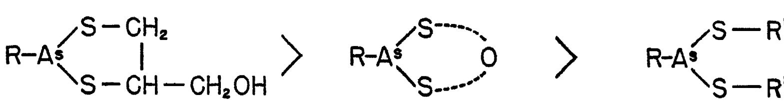
1. They will follow an adsorption curve type of action.
2. They are usually effective at very low dosage.
3. They have a persistent action.

To extend our analogy of simple ions, this type of action may be compared to removal of an ion. Thus if our metabolite was hydrogen ion, in the 0.1 N acetic acid, then addition of 0.1 equivalent of hydroxide ion reduces the $[H^+]$ to 10^{-7}. The base was the blocking drug, active

in low concentration, and not easily reversible. Clearcut examples of this type of action are not readily available, since the action is harder to study. However, "Hetrazan", N-methyl-N'-dimethyl-carbamidopiperazine, which is effective against filariasis, is active at relatively low dosage (about 300 mg./day), while Mapharsen is effective against syphilis at dosages of 40 mg./week.

The problem of the mechanism of drug action is more complicated than consideration of these two simple types of action would indicate. Since only a few of the possible "essential metabolite" steps are clearly understood, whereas thousands probably exist, there is a great possibility that chemotherapeutic agents may act on more than one site. This can be illustrated by some observations on arsenic poisoning, arsenicals, and British Anti-Lewisite.

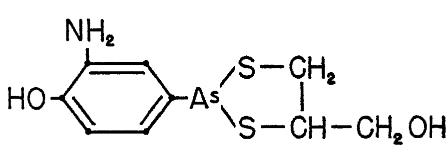
The suggestion by Voegtlin, Dyer, and Leonard (11) that arsenicals exerted their toxic effects through combination with sulfhydryl groups was brilliantly parleyed by the British investigators into the development of B.A.L. (7). During the course of these investigations it was shown that although a large excess of monothiol would reverse the toxicity of arsenoxide, dithiols were much more active. This is attributed to the greater stability of the ring compounds.



B.A.L. complex thiol enzyme complex monothiol complex

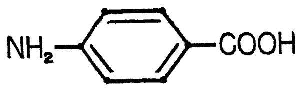
Since B.A.L. was quite effective in preventing, and even reversing, pathological damage by Lewisite, it was not surprising that "in vitro" tests showed that B.A.L. reversed the toxic effect of arsenoxides on trypanosomes, and it seemed apparent that the mechanism of action of the arsenicals was to interfere with sulfhydryl groups in the trypanosomes.

However, recently Friedheim and Vogel (4) reported that the compound formed by the combination of Mapharsen and B.A.L. (I):

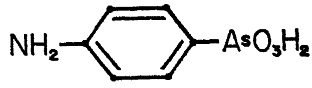


I

is quite active against both trypanosomes and spirochetes, although it is much less toxic than the parent Mapharsen. This indicates an entirely different site of toxic action in host and parasite. This is also indicated in the work of Sandground and Hamilton (8) who considered that the aromatic arsenicals (Atoxyl) might act as anti-PAB compounds, like the sulfa drugs.



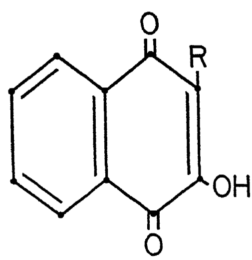
PAB



Atoxyl

During the course of experiments designed to test this hypothesis, it was discovered that administration of PAB on or before injection of Carbarsone protected rats against several toxic doses of the arsenical. No protection of the animals against trivalent arsenic or the arseno-compounds, and more remarkable, no inhibition of the trypanocidal activity of Carbarsone by PAB was observed!

Solvent effects and permeability are also important in considering the mechanisms of action of selective toxins. In several instances optimum actvity has been found to correlate quite closely with a certain distribution coefficient between water and fat-solvent. For example, Fieser, et al (2) found such a correlation in the antimalarial activity of a series of alkylhydroxynaphthoquinones (II).

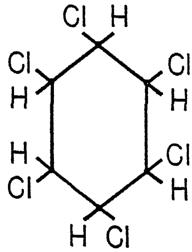


II

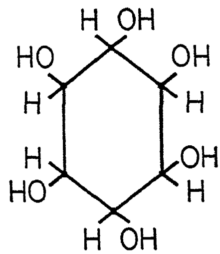
Blowfly larvae are unaffected by immersion for one hour in kerosene, or in absolute ethanol, but a mixture of kerosene and alcohol is toxic in a matter of seconds. This has been attributed to altered permeability of the cuticle (5).

The manner in which selective toxins combine with or displace essential metabolites is not always clear, but great emphasis must be placed on similarities in molecular structure. Bell and Roblin (1) were able to show the close relationship between the para-aminobenzoate ion and sulfanilamide. The activity of fluoroacetic acid as a rat-poison (1080) is at least partially due to its interference with the acetic acid oxidase system. Since chloroacetic acid does not interfere in this system, it has been assumed that the fluoro group may replace hydrogen in the acetic acid-enzyme complex, but the chloro-group is too large to permit formation of the complex.

Similarly the unusually high activity of the gamma isomer of hexachlorocyclohexane in the inhibition of yeast growth has been shown to be due to its similarity to inositol in stereochemical configuration (6).

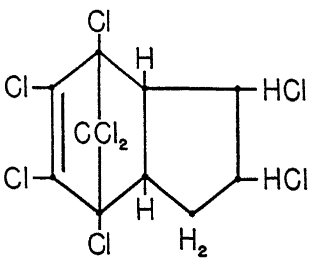


"Gammexane"

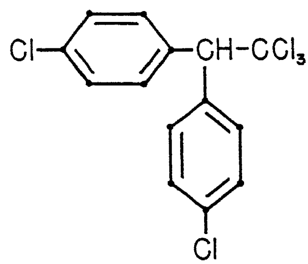


inositol

This similarity must permit blocking of some essential inositol reaction in yeast. On the other hand, no such relationship is apparent in its activity as an insecticide, and "gammexane" is grouped with other chlorinated hydrocarbons, such as chlordan (III) and DDT (IV), which are effective insecticides.



III



IV

The high activity of DDT against various insects has led to many studies on related molecules, and the mode of action, but no likely theory has as yet been developed. Some compounds tested against lice are reported in Table I, after Sexton (9).

It is apparent from these data that certain structural requirements are present for activity against lice. A functional group must be present on one of the benezene rings. This may be halogen or methoxy, but hydroxy inactivates the molecule. Only one substituted benzene ring is required, but the trichloromethyl group is essential, and is apparently not hydrolyzed "in vivo", since the coresponding acid is inactive. The gradual decrease in activity with increase in group size in the alkyl-

TABLE I. Toxicity to Lice of Certain DDT Analogs

$(p\text{-}ClC_6H_4)_2CHCCl_3$	+++	$(p\text{-}C_2H_5OC_6H_4)_2CHCCl_3$	++
$(C_6H_5)_2CHCCl_3$	+	$(p\text{-}C_3H_7OC_6H_4)_2CHCCl_3$	+
$(p\text{-}FC_6H_4)_2CHCCl_3$	+++	$(p\text{-}C_6H_5CH_2OC_6H_4)_2CHCCl_3$	0
$(p\text{-}CH_3C_6H_4)_2CHCCl_3$	++	$p\text{-}ClC_6H_4CHOHCCl_3$	+++
$(p\text{-}C_2H_5C_6H_4)_2CHCCl_3$	+	$p\text{-}ClC_6H_4CHClCCl_3$	+++
$(p\text{-}HOC_6H_4)_2CHCCl_3$	0	$(p\text{-}ClC_6H_4)_2CH\text{-}CHCl_2$	+
$(p\text{-}CH_3OC_6H_4)_2CHCCl_3$	+++	$(p\text{-}ClC_6H_4)_2CHCOOH$	0

and alkoxy-substituted compounds is significant, particularly in view of the loss of activity with the polar hydroxyl substituent which is comparable in size to the fluoro group. This indicates that the polarity as well as size is important in any "lock and key" theory which can be developed for the DDT series of compounds.

In summary, we may say that compounds are selective toxins when their molecular structure and chemical properties are such as to permit them to react with specific "chemoreceptors", which may be enzymes, to inactive the receptor either by displacing an "essential meabolite", or preventing formation of a necessary active complex. Only when the nature of the "chemoreceptor" is known can quantitative experiments be made which will confirm or deny the proposed mechanism of action.

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The Effect of pH on the Toxicity of Weak Acids and Bases[1]

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Purdue University, and Oxford University, England

Many of the most important substances which are toxic to bacterial and other living cells belong to one of the groups of weak acids or weak bases, and it has been realized for many years that if these toxic agents were applied to the organism at each of two pH levels the extent of the response might be widely different.

For example one might quote studies on the toxicity of phenylacetic and benzoic acids to *Escherichia coli* and *Staphylococcus aureus* which showed that these acids were much more toxic when applied at acid pH levels than when applied at a neutral pH (1). Conversely, using quinine alkaloids, i.e., weak bases, Michaelis (2) and others showed that the bactericidal action was much greater in slightly alkaline solutions, and similarly, increases in the pH value of the medium has been found to increase the toxicity of atabrine (3) in experiments on *E. coli*. Comparable effects of pH on the activity of weak acids and bases on a wide variety of biological processes have frequently been observed (4, 5, 6, 7). In general it is found that if a certain concentration of a toxic weak acid is applied at a series of pH levels and percent inhibition (of controls at the same pH) plotted against pH, one obtains a sigmoid curve which falls from 0% at one pH to 100% at a pH level a few units lower. The curve becomes displaced along the pH axis when different concentrations of inhibitor are chosen; if the concentration is a higher one the curve will be displaced to the right, and if it is lower, to the left. Such graphs show qualitatively that the inhibitor is more toxic in acid solution, and any single curve might be taken to indicate that the acid is not toxic at a high pH, but this conclusion is not justified because toxic effects could be readily observed at higher pH levels by increasing the concentration of the inhibitor.

The quantitative effect of pH can readily be shown in the manner used extensively by Simon and Blackman in work on the toxicity of nitrophenols to *Trichoderma viride* (4). This organism grows reasonably well at any pH between 3 and 8, and it was cultured at several levels within this range in the presence of finely graded concentrations of the toxic agent. For each pH level a graph was constructed on which per cent inhibition of growth was plotted against Log. concentration of inhibitor, and that concentration which induced a 50% response (L. D. 50) was read off from the steeply falling curve. These equi-effective concentrations were then plotted against pH on a further graph, and

[1] This paper was presented as part of a Symposium on Selective Toxicity.

a curve of the type A shown in Figure 1 was obtained. It can be seen that at a low pH, say 4.0, the L. D. 50 was about 10^{-5}M. but at pH 8.0 the concentration of nitrophenol required to produce the same response was more than 100 times greater. When 2:4 dinitrophenol, which has a pK (pH at which it exists equally in the dissociated and

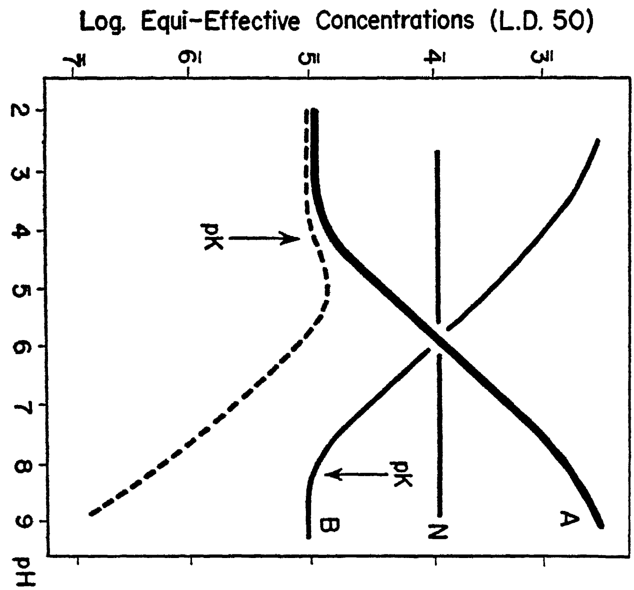

Fig. 1. The determinative effect of pH on the concentration of A, a weak acid, B, a weak base, and N, a non-electrolyte required to induce a standard response. (See text).

undissociated forms) of 4.0 was used, the rise in the curve A began, as shown, when the pH was raised to levels beyond this. With p-nitrophenol, we get the same type of curve but again, the rise does not begin until the pK (7.1) is exceeded; if picric acid (pK 0.8) was used there would be no level part to the curve in the working range pH 3-8.

In general then, at pH levels below the pK of the particular acid the curve levels out; changes in pH in this range have little effect on the concentration of inhibitor required to produce a standard response. As the pH is raised above pK increasingly greater concentrations of inhibitor are required to produce this same response.

Conversely, for weak bases, a mirror image of curve A is obtained, and, as for acids, its placement along the pH axis depends on the pK of the particular compound being used. The bases are most active at alkaline pH levels above pK, where the curve is flat, and as the pH is lowered past pK the curve of L. D. 50 rises sharply.

We note here that a straight line would be obtained for a plot of L. D. 50 values against pH in the range 3-8 if the substance under

investigation was a weak acid with a very high pK (greater than 8) or a weak base with a very low pK (lower than 3). Similarly, changes in pH would have little effect on the activity of non-electrolyte inhibitors. The foregoing considerations show that widely different values for the toxicity of a compound can be obtained at different pH levels and emphasize the need for choice of a suitable pH for toxicity measurement. It is also necessary to maintain rigid control of pH during the measurements because a change of one unit may conceivably make the observed result different from the true value by a factor of some 6-8 times. The pH of the medium is also a factor in experiments in which materials are added which overcome the toxic effect or modify it in some way. These materials may have acidic or basic properties, their effect may well be quite an indirect and unspecific one, if the pH of the medium changes due to their addition.

pH considerations are of great importance too in work on comparative toxicities of a group of compounds. This may best be illustrated by reference to a hypothetical case in which the toxicity of 3 different substances are being compared (Fig. 1). Curve A is that of a weak acid with pK of 4, and B of a weak base with pK of 8. N represents (a) a non-electrolyte, (b) a weak acid with pK greater than 8, or (c) a weak base with pK less than 3. From the graph we can read off the L.D. 50's of these compounds at any pH level, and if we chose three such levels arbitrarily we get the following results.

(1) At pH 4.0 L. D. 50 A 10^{-5}M.
L. D. 50 B 10^{-4}M.
L. D. 50 N 10^{-3}M.

A is 100 times as effective as C.

(2) At pH 6.0 L. D. 50 A, B, N is 10^{-4}M.

All are equally toxic.

(3) At pH 8.0 L. D. 50 A 10^{-3}M.
L. D. 50 B 10^{-4}M.
L. D. 50 N 10^{-5}M.

C is 100 times as effective as A

We see that no valid general statement of comparison is possible; it must be qualified by information on pH and on the pK of the compounds concerned. To overcome this difficulty it is suggested (4, 7) that values for maximum toxicity should be compared. This entails finding L.D. 50 values at pH levels below pK for acids and above pK for bases, where the toxicities are greatest and where small changes in pH have little effect on the result. This suggestion is practical enough for compounds with pK values in the range 3-8 but may be difficult for compounds with pK values outside this range, e.g. it would not be feasible to investigate the reaction of an organism to a substance having a pK of less than 2-3 in this way because the organism would not tolerate such a low pH.

However, on the basis of data from a number of different fields of inquiry Simon (6) has now constructed what we call a general curve (A) which shows the relation between activity (toxicity) and pH for any weak acid. From this relation, if the toxicity at one pH is known, for a particular acid of known pK, the toxic level at pH levels below pK can be calculated. This is really a means of calculating the potential or maximum toxicity of a compound. It might be more important in a particular case to know the toxic concentration at a particular pH, but in seeking for an interpretation of toxicity in terms of biochemical reactions the potential or maximum toxicity is a very useful measure.

It might be asked what is the explanation of these rising curves and why it is that acids are more toxic at low pH levels and bases at high ones. In other words, why does pH of the medium affect the amount of toxic material entering the cell and reacting inside? In the first place we can discount the hypothesis that as the pH level is changed the permeability of the cell to the inhibitor is changed, because wherever in the pH scale the pK occurs, changes in pH beyond this have no effect on the L.D. 50, (and for non-ionizing substances equi effective concentrations are the same at all pH values.)

We have then to consider the effect of pH on the extent of the ionization of the weak acid or base. From qualitative or semi-quantitative studies it has been suggested that since toxicity of acids increases in acid solution where there is a higher concentration of undissociated molecules of the acid, it is this concentration, and not the total concentration of applied inhibitor which produces the response. There seems to be little doubt that the extent of dissociation of the added acid is a major one in determining the toxicity, since it is well established that undissociated acid molecules penetrate more readily that acid anions. The hypothesis that only undissociated molecules are active infers that the ions do not penetrate at all, and this has been assumed to be completely true in analysis of pH effect of phenols on bacteria by Cowles and Klotz. We can test this hypothesis directly on any or all of the curves shown where L.D. 50 is plotted against pH.

We know that the following relation holds between pK and pH and the concentration of molecules and ions of the acid or base.

$$\mathrm{pH} = \mathrm{pK} + \log \frac{[\text{dissociated acid}]}{[\text{undissociated acid}]}$$

From this equation, since we know the total concentration of acid for any point on the L.D. 50 curve we can calculate what concentration of undissociated molecules exists at that total concentration.

Now if the hypothesis that only the external concentration of undissociated acid determines the response is true, we would expect that the plots would be in a straight line, since the same response is observed in each case.

The broken line in the figure shows the result of such a plot and it is clear that we find a curve which falls sharply as the pH is changed beyond pK. Since we do not get the straight line required by the above

hypothesis, it is clear that the concentration of undissociated acid molecules is not the only factor determining the response. Higher concentrations of inhibitor are needed to produce the effects at higher pH levels, but these concentrations are not so much higher as one would have expected on the hypothesis referred to.

It must therefore be allowed that some other factor, probably the concentration of acid anions has an increasing effect as the pH is altered beyond pK. The possible interpretations are discussed elsewhere by the present authors (7).

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Antibiological Polypeptides as Illustrated by Circulin[1]

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Introduction

In the summer of 1946 Murray and Tetrault (8) began a search for new antibiotics active against gram-negative organisms. This seemed appropriate because at that time no drug was available that would serve as specific remedy against such diseases as typhoid fever, paratyphoid fever, dysentery, cholera, certain kidney infections, etc.

Since several members of the genus *Bacillus* were known to produce peptide antibiotics that were relatively toxic, Murray (7) avoided picking aerobic spore-forming bacilli as potential antibiotic-producers. It was indeed fortunate for the development of circulin that, for a short while at least, he considered his soil isolate Q-19 to be a non-spore-forming organism; otherwise he probably would have discarded what turned out to be a promising if slightly unorthodox strain of *B. circulans*. In further studies on the antibiotic products of this organism Murray and Tetrault were joined by Koffler, Kaufmann, Quinn, Napoli, Perry, Reitz, and Dowling at the Purdue laboratories, by a group led by Peterson and Colingsworth at the Upjohn Company, by Nash at Pitman-Moore, and by workers at various medical institutions.

Biological properties

These studies have shown that *B. circulans* Q-19 produces several antibiotics (in this paper referred to as circulin fractions 1, 2, and 3) that appear to be chromatographically different (3, 11, 14). Circulin is both biologically and chemically similar to the five known polymyxins (A, B, C, D, and E), which are antibiotic polypeptides produced by various strains of *B. polymyxa* (1,2,3,5,9,10,11,13,14,15,16,18). Like them it is selectively active against many gram-negative bacteria such as members of the *Enterobacteriaceae*, to which several intestinal parasites and also the plant pathogen *Erwinia* belong (1,9,13,15,18). Interestingly enough *Proteus* and *Serratia* are the only genera of the *Enterobac-*

[1] The antibiotic described in this review is not identical with the highly toxic product of *Bacillus krzemieniewski* M-14, which for a brief period of time was also known as circulin but which is now called polypeptin (4, 6). The author is grateful to his coworkers at Purdue University and Dr. Harold Nash of the Pitman-Moore Company in Indianapolis for graciously making available unpublished data that were summarized in this review. Much information on the structure of circulin (fraction 1) was contained in a correspondence between Dr. R. G. Sheperd, of the American Cyanamid Company, Stamford, Connecticut, and Dr. D. H. Peterson, of the Upjohn Company, Kalamazoo, Michigan. The author is indebted to Dr. Peterson for enabling him to benefit from this exchange of letters.

This paper was presented as part of a Symposium on Selective Toxicity.

teriaceae that are strikingly resistant to circulin (9, 13, 18). Not only is circulin active *in vitro*, but it also was shown to protect white mice from infections caused by *Klebsiella pneumoniae*, *Salmonella typhosa*, and *Vibrio cholerae*, and to be useful in the control of human kidney infections caused by members of the genus *Pseudomonas* (1,9,13,15). This pronounced action against certain gram-negative bacteria together with the fact that such organisms develop resistance to circulin only with difficulty (10,18) make it a potentially useful therapeutic agent, especially against infections caused by pathogens that have become resistant to other drugs. However, circulin is fairly toxic to experimental animals (9,13,15,16), and at this stage should be used only in clinical trials.

Little is known of the mechanism by which circulin acts against susceptible cells. It appears to be bactericidal (10,18), and in many ways behaves like a cationic detergent. However, cationic detergents tend to be more active against gram-positive bacteria than they are against gram-negative organisms; the opposite is true for circulin. Whether the mode of action of circulin depends upon the physical disintegration of the cytoplasmic membrane, metabolite-antimetabolite relationships, etc., still remains to be demonstrated.

Preparation

Circulin has been produced by growing *B. circulans* Q-19 either in shake flasks (9,12,15) or in 100-gallon pilot fermenters (12) in relatively simple media (9,12,15). As in other submerged fermentations the composition of the media, the pH, the degree of aeration and agitation, etc., are critical (9,12). Under optimum conditions the organism gives yields equivalent to approximately 1 mg. of pure circulin fraction 1 per ml.; however, about 60% of this is lost during recovery. In the pilot plant extraction procedures have been used with sulfonated alkyl aryl compounds (Ultrawet and Onyx Aliphatic Ester Sulfate) as specific precipitants. The circulin complexes formed on addition of these compounds dissolve when treated with acidified aqueous n-butanol or acetone, and circulin salts (for example sulfates when sulfuric acid is used to acidify the organic solvents) precipitate and are recovered (12). In the laboratory circulin fractions can be prepared by a method that in brief includes adsorption of the antibiotics from the clarified culture filtrate on activated carbon (Darco G-60) and elution with acidified aqueous tertiary butanol solutions (9,14). Further separation of the fractions can be achieved with a Celite 545, n-butanol, citrate-HCl system (3,11). The determination of purity in the case of polypeptides is very difficult. Usually one continues purification until the product shows constancy of composition, solubility, and biological activity; homogeneity of chemical and physical properties, etc. Unfortunately many organisms produce a series of compounds structurally so related that their separation becomes practically impossible. Even worse, frequently work is done on what appears to be a pure material and then turns out to be a mixture of substances. The history of circulin illustrates these points.

Peterson and Reineke (14) did some impressive chemical work on a compound (circulin fraction 1) that they obtained after repeated chromatography over Darco G-60 and that they considered to be essentially homogenous. One of the criteria used to establish this was that fraction 1 could not be resolved into more than one component by paper chromatography, with a developing solution that consisted of 25% water, 50% n-butanol, and 25% glacial acetic acid. By the time they had finished their chemical studies they had used up all of fraction 1. When Nash (11) later tried to repeat isolation of fraction 1 from less pure batches of circulin he found that he could isolate at least two components (the faster moving fraction 2 and the slower moving fraction 3) using chromatography with his Celite 545, n-butanol, citrate-HCl system. It seems significant that Peterson and Reineke's solvent system usually is not capable of accomplishing the separation of fractions 2 and 3 on paper chromatograms, while a system composed of the following does allow separation: 49.5% water, 49.5% n-butanol, and 1.0% glacial acetic acid (3,11). This observation raised the question of whether Peterson and Reineke had dealt with a single antibiotic (probably identical to fraction 2) or with a mitxure of fractions 2 and 3. Since Peterson and Reineke's fraction 1 was exhausted by analysis this cannot be answered with certainty. Recent data, however, make the first possibility more likely. Using Peterson and Reineke's method of purifying circulin, Peterson (3) was able to resolve impure circulin into two or more components, one of which behaved chromatographically the same as did his previous fraction 1 or Nash's fraction 2. This preparation appeared homogenous on paper chromatograms even when a solution of 49.5% water, 49.5% n-butanol, and 1% glacial acetic acid was used. Apparently Peterson and Reineke's original developing system (14), though incapable of separating fraction 1(=2) from fraction 3 on filter paper, did permit resolution when Darco G-60 was used as supporting material. In connection with the purity of the circulins it should be remembered that all the biological studies mentioned previously were made with preparations that contained two or more components.

Chemical properties

Circulin fraction 1 is a basic polypeptide that can be converted easily into its picrate, helianthate, reineckate, hydrochloride, sulfate, etc. The sulfate and hydrochloride of fraction 1 are highly soluble in water, and relatively insoluble in water-immiscible solvents. Fraction 1 was reported to have the same qualitative composition as polymyxins A and E, and all three antibiotics contain L-threonine, D-leucine, L-α, γ-diaminobutyric acid (DABA), and a fatty acid with the properties of 6-methyloctanoic acid (2,5,14,17). In fraction 1 these constituents are thought to occur in a ratio of 1:1:5:1, and the amino acids have been assumed to be arranged in a cycle (14). Peterson and Reineke (14) based their claim for the existence of such an arrangement on 1) the amino acid composition; 2) the fact that approximately one-half of the amino nitrogen of circulin is uncombined (the amino nitrogen before hydrolysis was 7.5 per cent after hydrolysis 15.8 per cent); 3) the

absence of free carboxyl groups as shown by titration curves and a negative ninhydrin-CO_2 (Van Slyke) test; and 4) evidence that the amino groups of DABA were the only free amino groups in circulin. The fourth line of evidence is subject to some question and is being reinvestigated (3). It was based on the observation that the 2,4-dinitrophenyl (DNP) derivative of circulin when hydrolysed with hydrochloric acid apparently yielded no other products than DABA, α-amino-γ-(2,4-dinitroanilino)-butyric acid, threonine, and leucine, as observed by paper chromatography. However, since DNP derivatives of monoamino acids do not react with ninhydrin, which was used to indicate the position of the various components on the chromotogram, and are visible only by their yellow color, small quantities of such derivatives may have escaped detection. Moreover, the fact that not all of the DABA was converted to its DNP derivative raises the question of whether this was true because the dinitrophenylation reaction was not carried to completion or because some DABA is combined in the intact molecule. Inasmuch as the dinitrophenylation was performed in the absence of alcohol, a condition under which the reaction is thought not to go to completion (3), the first alternative seems more likely. DABA is not formed from its DNP derivative by acid hydrolysis (3), and this possibility can therefore be excluded as an explanation for the occurrence of free DABA on the chromatogram. Although it is plausible that circulin has a cyclic structure, as presented in the generalized formula given in Figure 1, the contentions that all of its free amino groups are furnished by DABA

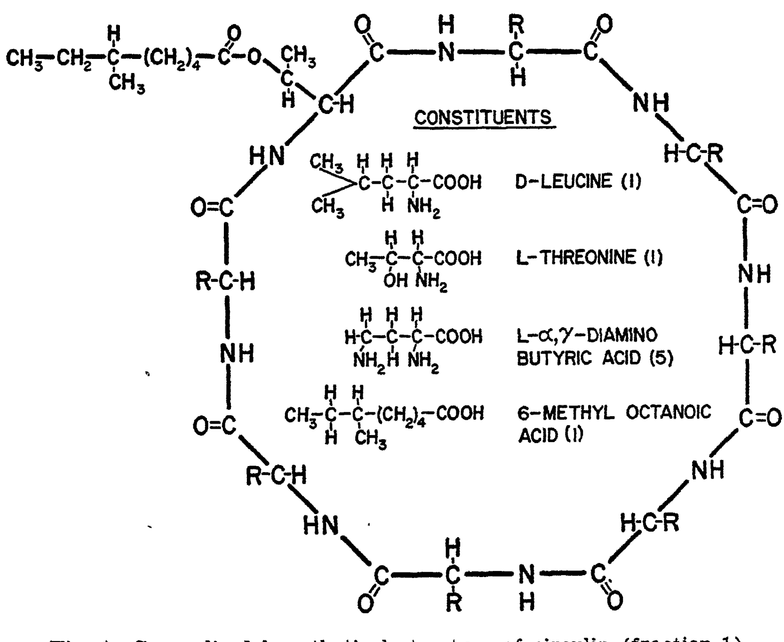

Fig. 1. Generalized hypothetical structure of circulin (fraction 1).

and that all DABA side chains are unsubstituted still remain to be verified. Proof of these and of a cyclic structure is prerequisite also to an interpretation of the behavior of circulin in the presence of lipase. Circulin, and polymyxins B and E are inactivated by lipase, while polymyxins A and D are not (3,14); polymyxin C has not yet been tested. The fact that circulin is inactivated by lipase has been regarded as suggestive evidence that 6-methyloctanoic acid is joined to the polypeptide through threonine by an O-acyl linkage (14), as is tentatively visualized in Figure 1. This needs to be so only if circulin is a cyclic polypeptide, all of its free amino groups are furnished by DABA, and all DABA side chains are unsubstituted, conditions that have not yet been met fully. One will also have to demonstrate that the lipase preparation used is able to hydrolyze O-acyl but not N-acyl linkages. Isolation of the fatty acid and the intact polypeptide after inactivation of circulin by lipase, and demonstration that a hydroxyl group rather than amino group becomes liberated during inactivation are necessary before any view on the manner in which the fatty acid is attached to the rest of the molecule can be accepted (3). If all these requirements are fulfilled it will be interesting to see whether the polymyxins and circulins can be divided into those in which the fatty acid is attached through an N-acyl linkage and those in which an O-acyl linkage exists.

Since it was claimed that fraction 1, and polymyxins A and E have qualitatively the same composition, it became necessary to determine whether these three were different antibiotics. That fraction 1 and polymyxin A are not identical became apparent from their different resistance to inactivation by lipase (14). However, polymyxin E was not available for comparative work at that time, and the possibility could not be ruled out that fraction 1 and polymyxin E were the same. Since fraction 1 was not available for further comparison, fractions 2 and 3 were eventually studied chromotographically, and found to be different from polymyxin E (3). However, another uncertainty still clouds the issue. Nash (11) recently has obtained preliminary evidence that both fractions 2 and 3 contain another amino acid, probably isoleucine. Although this evidence remains to be examined more thoroughly, it suggests that the circulins 1 and 2, contrary to previous notions, may differ from polymyxin E in qualitative composition. Confusing as the situation may be, it is rather typical of the manner in which our knowledge on the nature of antibacterial polypeptides evolves. This, however, is no consolation and it is somewhat discouraging to reflect upon the prospect that a few years from now circulin may be found to consist not of two or three but of several entities.

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Chemical and Physiological Studies on Paramecin and Kappa[1]

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Paramecin is the end product of the system gene K-Kappa-paramecin which is present in some stocks of *Paramecium aurelia* of varieties 2 and 4. The killer and sensitive characters have been most fully studied in variety 4 of stock 51 by Sonneborn and his associates(2).

When sensitive stocks of variety 4 are exposed to fluid in which the killer stock 51 has grown they develop characteristic morphological changes. A slight hump appears after several hours on the aboral surface near the hind end of the body. This hump enlarges while the anterior end of the body gradually wastes away and the posterior part is pushed into the humped region. The animals then become smaller and finally die. Sensitives can be mated to killers without any evidence of injury, if mating begins soon after the two kinds of paramecia are brought together, if the conjugant pairs are removed to fresh culture fluid soon after they unite, and if the two members of each pair are put into separate culture dishes soon after conjugation has been completed.

The killer phenotype is manifested only when there is present in the cytoplasm a factor designed as "kappa". In the absence of kappa the phenotype is invariably sensitive. The presence of kappa is related to the genetic constitution. Clones of killers always have in the nucleus a dominant gene K, either in homozygous or in heterozygous condition. If the allele k is substituted for gene K, the kappa which is initially present in the cytoplasm soon disappears. Once kappa has disappeared from the cytoplasm it cannot be brought back by restoring gene K. Sensitive stocks, therefore, might have either allele, K, or k, for kappa is not initially producible by any known gene.

The relations between K and kappa are illustrated by the following. When a cross is made between killers and sensitives both of which are homozygous for K, each member of a conjugant pair usually gives rise to a clone of the same character as the parent from which it derives the bulk of its cytoplasm. Normally there is no cytoplasmic exchange between the mates, hence usually the killer conjugant produces a killer clone and the sensitive conjugant produces a sensitive clone. Under certain conditions, however, exchange of cytoplasm does take place between the mates. When this happens, both mates produce killer clones. When cytoplasm is introduced into a sensitive animal containing the

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gene K, kappa is maintained and multiplied thereafter in all subsequent vegetative and sexual reproduction. The function of gene K seems to be to control the maintenance and increase of kappa when some is already present, although it cannot start the production of kappa when none is initially present.

Biochemical investigations on the nature of paramecin have shown the following: 1. Paramecin is unstable at each pH ranging from pH 5 to pH 9.5. Paramecin is most stable at a pH 8.5. Even at this pH approximately 15% of its original activity is lost after one hour incubation at 30° (2); 2. Paramecin is inactivated by treatment with pepsin, chymotrypsin and desoxyribonuclease. Its activity is not affected by treatment with ribonuclease. It can therefore be concluded that biological activity of paramecin is associated with a desoxyribonucleoprotein (3). Preer (1) has shown that desoxyribonucleic acid is a component of the cytoplasmic factor kappa. The three components of the gene-kappa-paramecin-system have therefore in common that all contain desoxyribonucleic acid.

Respiratory studies, using the Cartesian diver technique, have revealed that there exist striking and significant differences in the respiration of animals possessing kappa and those which lack this cytoplasmic factor. Comparisons were made between sensitives and killers grown under identical conditions. The first group, stock 29.7, is a sensitive stock, having the recessive genotype. It has no kappa in its cytoplasm and it cannot support the growth of kappa. The 51.7 stock used for comparison has kappa in its cytoplasm and can maintain it due to the presence of the dominant killer gene. The Q_{O_2} of animals of stock 29.7 was found to be 0.457 ± 0.037 mμl/animal-hour, as compared to 0.871 ± 0.090 mμl/animal-hour for animals of stock 51.7. However, the possibility that this difference might be due to a stock difference is not excluded, since the two stocks have different genetic backgrounds. A further comparison shows that the sensitive animals which differ from the killer animals only in the absence of kappa in the cytoplasm also have a respiratory rate approximately one half as great as that of the killer animals, the Q_{O_2} being 0.510 ± 0.032 mμl/animal-hour and 0.899 ± 0.085 mμl/animal-hour respectively. The respiration of a culture isogenic with 51.7 killers was also compared with the respiration of 51.7 killers. Stock 186.7 was obtained by a series of successive backcrosses of 29.7 sensitives by 51.7 killers, and differs from the killer stocks in the presence of the recessive gene at the killer locus. Again the 51.7 killer stock respires at approximately double the rate of the 186.7 stock, the Q_{O_2} in this instance being 0.962 ± 0.054 mμl/animal-hour, and 0.546 ± 0.042 mμl/animal-hour for the two stocks.

To summarize, here we are dealing with a gênetic system in *Paramecium aurelia*, that on the one hand produces an antibiotic, and that on the other hand induces an immunity to this antibiotic. Both the production of the antibiotic and the expression of immunity are

under control of a cytoplasmic factor. Whether an animal is immune to the antibiotic paramecin is dependent upon the concentration of the cytoplasmic factor. Sonneborn (1) has shown that the concentration of kappa can be reduced to such an extent that the resulting paramecia are resistant non-killers. If the concentration of kappa is still further reduced the animals become sensitive non-killers.

Selective antibiosis and respiratory rate are both correlated with the cytoplasmic factor. Our observations to date are mostly confined to the overall processes of respiration and do not take into account possible finer differentiations. That these exist is demonstrated by the following: the overall respiration of KK sensitives, 186.7 sensitives and KK killers is differently influenced by azide. The respiration of KK sensitives is inhibited 50% by $10^{-3.5}$M azide, that of 186.7 sensitives is not inhibited by the same azide concentration, while the respiration of the KK killers is enhanced by this concentration of azide. Definite different enzymatic sequences must take place in these stocks to account for the difference in behavior towards the inhibitor. It is possible that these different enzymatic reactions direct selective antibiosis. The postulates of comparative biochemistry, stating that all living things utilize essentially the same reactions in their life processes would still be valid. Sensitives and killers would differ because some additional reactions take place in the killers caused by the presence of the cytoplasmic factor. It might perhaps be possible that selective antibiosis is due to the existence of hitherto unsuspected genic and cytoplasmic differences between different stocks.

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Mechanisms of Action of Clostridial Toxins[1]

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Study of the clostridial toxins has been irregular. During World War I the further identification and characterization of the clostridia causing gas gangrene and tetanus were ably pursued, and demonstration of the existence and harmful action of clostridial exotoxins were emphasized. Use was made of this knowledge for diagnostic purposes and for the preparation of toxoids and antitoxins (23). At the onset of World War II several important observations were at hand which permitted a more fundamental approach to the description of the modes of clostridial toxic action. It is hardly surprising to find that the more recent approach is of a biochemical character, for it was shown that many of the toxic mechanisms involved enzymatic reactions. Since knowledge of the intimate reactions resulting in toxic effects upon the host must of necessity include the characterization of *how* a toxin functions, elucidation of the enzymatic basis of toxic action constitutes a real contribution to an understanding of the problem (21, 22). With the renewed interest and activity experienced during World War II which resulted, among other findings, in the crystallization of the tetanus and botulism toxins (18), it became ever more apparent that the clostridial toxins are the most potent poisons known, indicating a catalytic rather than a stoichiometric mode of intoxication.

The intoxication of botulism was long known to be caused by an extracellular growth product of *Clostridium botulinum* and to involve the nervous system, as indicated by such symptoms as oculomotor, pharyngeal and respiratory paralysis. It was shown in 1936 by Bishop and Bronfenbrenner (4) that the toxin acted upon the myoneural junction, resulting in an interference with acetylcholine action upon the muscle, the mode of action of curare. More recent data (9, 24) indicate that acetycholine still causes muscular contraction after botulinus poisoning, an effect not obtained under the conditions of curare poisoning, but that decreased synthesis of acetylcholine occurs during botulinus poisoning. Torda and Wolff (24) found that the rate of acetylcholine synthesis by frog or mouse brain was inhibited appreciably by small amounts of botulinus toxin. Burgen, Dickens and Zatman (5) concluded that since conduction in the nerve of the poisoned muscle is unaffected by the toxin and since the muscle responds normally to direct stimulation, the mechanism of paralysis involves a neuro-muscular block at the motor end-plates which themselves remain sensitive to acetylcholine. The reduced output of acetylcholine by the poisoned muscle results, therefore, in the interference with impulse transmission from the nervous system to the muscle. Exactly how the botulinus toxin inhibits acetylcholine synthesis remains to be shown. The toxin was found to have no effect upon the enzyme catalyzing the acetylation of choline nor upon

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cholinesterase, but still to be investigated are the effects of botulinus toxin upon acetate and choline synthesis or availability, and upon the enzymatic transfer of high-energy phosphate bonds to acetate from adenosinetriphosphate to yield the acetyl phosphate apparently required for acetylcholine synthesis.

Tetanus is a toxemia due to a localized infection of injured tissues by *Clostridium tetani*, the disease being characterized by convulsive tonic contraction of voluntary muscles. The extracellular toxic product inducing the muscular spasms has been termed tetanospasmin, the resulting muscular rigidity and intermittent periods of intense motor activity clearly suggesting an imbalance in some neuromuscular regulatory mechanism. The finding of increased acetylcholine levels in the muscle of animals injected with tetanus toxin has led to the conclusion by some workers that the enzyme hydrolyzing acetylcholine, namely cholinesterase, is inhibited by the toxin (8, 10, 25, 27). However, other workers (14, 20) were unable to demonstrate the inhibition of cholinesterase activity in the nervous tissues and blood sera of tetanized and normal animals. The problem with respect to cholinesterase, therefore, remains unresolved. A rather comprehensive study of the effect of tetanus toxin upon certain energy-liberating reactions was made by Muntz (14): neither the glycolysis of mouse brain nor the adenosinetriphosphatase of several nervous tissues and muscle were affected by the toxin. Nor were the levels of blood glucose and lactic acid affected. Indeed, this work indicates that there is no interference with the anaerobic energy metabolism of tetanized animals although numerous other energy-liberating systems remain to be investigated. In addition, Muntz attempted to find changes in the quantities of free amino acids and ammonia excreted by mice treated with huge quantities (100,000 MLD) of tetanus toxin; again no changes over the normal values were reported. He also attempted to detect a substance which might be liberated from tetanized nerve and muscle tissues, and which might be the actual toxic agent inducing tetany; no such agent was found. In the presence of all these negative data, it can only be restated that the mechanism of tetanal toxic action remains obscure.

The toxins produced by the agents of gas gangrene, bovine hemoglobinuria and other diseases caused by related clostridia are considered together because of the existence of some overlapping pathological properties and enzymatic similarities. Several members of the genus *Clostridium* produce proteinases which are important toxic agents because of the large amounts found extra-cellularly and because of the powerful proteolytic activities of these enzymes upon native tissues. Weil, Kocholaty and their associates (11, 12, 28), as well as others (3, 15), have studied the clostridial proteinases, particularly those of *C. histolyticum*, obtaining purified enzyme preparations which require ferrous ions and cysteine for maximum activity. Since these proteinases are secreted by clostridia found in tissue infections leading to the massive disintegration and liquefaction of muscle, the proteinases have been incriminated as specific toxic agents in such infections.

Related to the proteinases is the exo-product, fibrinolysin, obtained by Reed, Orr and Brown (19) from cultures of gas gangrene clostridia. This substance is relatively thermostable (100 C/1 hr) and thus distinguishable from the usual proteolytic enzymes. As indicated by its name, fibrinolysin can act as a contributing agent in a toxic infection by dissolving fibrin and thus permitting spread of the infecting agents.

Closely related to the proteinases and fibrinolysins is the enzyme collagenase (3, 15, 16, 25). Extracellular growth products of *C. histolyticum*, *C. perfringens* and *C. sporogenes* have been shown to include collagenases, and the pathological effects of these substances have been ascribed to their capacity to attack the collagenous connective tissue fibers, resulting in tissue breakdown and increased diffusion of the overall infectious process. Lethality and collagenase activity have not always been found to be related directly, thus indicating only a contributory role of this enzyme in the pathological process.

Another mechanism responsible for the spreading of infections in the host as a result of the microbial elaboration of an assemblage of substances involves extracellular products previously referred to as spreading factors. The viscous mucopolysaccharide of the mesenchyme, often called the ground substance of tissues, contains hyaluronic acid, a term used more to represent a class of substances than a single compound. This substance appears to be a polysaccharide composed of disaccharide units of acetylglucosamine and glucuronic acid. The enzyme hydrolyzing this substance has been called hyaluronidase and its primary action is upon the glucosamine linkage, releasing the reducing group of the acetylglucosamine (7). In this process, the substrate is depolymerized and becomes less viscous, and with regard to its anatomical function as a supporting tissue, the hyaluronate-containing tissue becomes less rigid. Since this enzyme(s) is produced by some of the clostridia causing gas gangrene (*C. perfringens*, *C. novyi*, *C. septicum*), its toxic role has been interpreted as involving the physical enhancement of further invasion by the infective agents into the surrounding tissues from their previously localized position, and the facilitated circulation of their toxic end-products. Although many reports indicate a relationship between hyaluronidase production and virulence, potent hyalurondase producing strains have been found which are neither associated with any particular toxin type nor related directly to the lethal potency of a given toxin (23).

The last group of toxic clostridial exo-enzymes to be discussed are the lecithinases. A great deal of work has been performed in this field during the past decade, especially by British investigators (21). When it was found that the toxicity of clostridial culture filrates often parallels the capacity of the filtrates to split lecithin into a diglyceride and phosphocholine, most workers concluded that the mechanism of toxic action in gas gangrene and bovine hemoglobinuria involves the direct participation of a lecithinases (D). Lethality, necrosis and hemolysis have been attributed to the attack by this enzyme of the lecitho-proteins of cell membranes with the subsequent breakdown of vital tissues such

as nerve and cardiac muscle, leading to toxic action and death. Moreover, specific antitoxins have been shown to inhibit the lecithinase activity of *C. perfringens* toxins, and it appears valid to conclude that the antitoxins are really anti-lecithinases (30).

Related to this lecithinase is another product of lecithinase activity, described by Bard and McClung (2) in the toxins of *C. novyi* type B and *C. hemolyticum*. In the latter cases lecithinase A production by the clostridia leads to the formation of lysocethin—a powerfully hemolytic substance—or lysolecithoprotein itself is synthesized by the organisms. This hemolytic substance, an important factor in snake venom intoxication, was found in culture filtrates which also contained lecithinase D. Thus, at least two mechanisms of hemolysis are found among some of the clostridial toxins: the more common lecithinase D and the hemolytic substance, lysolecithin.

In 1948 McClung and Russell (13) found strains of *C. perfringens* yielding highly lethal toxin but with low lecthinase D activity, and vice-versa. In the case of *C. novyi* toxins, Oakley, Warrack and Clarke (17) noted that lethality and lecithinase D activity were not related, and the same conclusion was made independently by Bard (1). Wooldridge and Higginbottom showed (29) that *C. perfringens* toxin inhibited the aerobic oxidation of succinate by aqueous extracts of minced guinea pig intestine, muscle, heart, liver and kidney, the inhibition apparently interfering with the transfer of hydrogen from the substrate to the cytochrome system; specific antitoxin reduced this inhibition. On the other hand, the toxins of *C. novyi*, *C. septicum* and *C. tetani* had no effect upon succinate oxidation. These findings indicate an additional site of toxic action by members of the gas gangrene group, one apparently separate from lecithinase activity. Presented with these data, as well as others with lecithinase D producing species of the genus *Bacillus* (6), which are considerably less toxic, the possibility arises that all the toxic mechanisms attributed to lecithinase D may be in excess (23). Aside from the complication that explanation of the toxic mechanism remains incomplete to this extent, doubt arises concerning the validity of using the lecithinase test in the practical problem of assaying and controlling large-scale toxin production for the preparation of wholly effective toxoids and antitoxins.

As has been the case with the descriptions of all the clostridial toxic mechanisms presented, many gaps exist in the present knowledge of this field. A more complete comprehension of the mechanism of toxicity can only be the result of continuous study of the clostridia and their toxins and this field awaits many future contributions.

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Methods of Evaluating New Antiseptic Agents

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The evaluation of the antibacterial activity of new antiseptics has been and still is a major problem confronting bacteriologists. Many tests have been devised to determine the antiseptic qualities of various compounds. No single one of these tests, however, is without its limitations and deficiencies.

Consequently, in attempting intelligently to evaluate any agent, a testing program must be devised which includes as many different types of antiseptic tests as are feasible. Especially in the case of the comparatively new quaternary ammonium cationic compounds is the foregoing true. These compounds have been enjoying increasing popularity for use as antiseptics. Their antibacterial activity in high dilutions has brought them into demand in industries where there is a need for economical and efficient chemical sterilizing agents.

The question now arises, what various tests should be done in order to determine the activity of an antiseptic? The answer to this, of course, depends upon the properties which you desire to determine in a given germicide. Recently, Salle and Catlin (3) made an excellent suggestion for the evaluation of germicides. They recommended that, in the evaluation of an antiseptic, tests should be carried out which would determine the following minimum properties of antiseptics: (1) the highest dilution of germicide capable of killing *Micrococcus pyogenes* var. *aureus;* (2) extent of bacteriostasis; (3) influence of organic matter; (4) speed of action; (5) penetrability; and (6) toxicity.

For this purpose the following tests were recommended: (1) modification of the FDA test for determining the killing dilution against *M. pyogenes* var. *aureus;* (2) bacteriostatic tests in 10 and 100 ml of FDA broth and thioglycollate medium; (3) similar tests in the presence of 10% serum; (4) tests for killing, in time periods of from 1 to 10 minutes; (5) penetration tests, using the FDA agar cup plate method; and (6) toxicity tests on embryonic chicken heart tissue.

According to Reddish (2), "Studies of this character give considerable information relative to the properties of antiseptics. In fact, a combination of these tests will give information from which the practical value of an antiseptic may be predicted, or at least they will reflect its potentialities. Furthermore, the methods employed are all standard procedures that have been used separately for some years . . . . Since each test shows certain specific properties of antiseptics, collective results give a correct and useful profile of the antiseptics tested."

In addition to these minimum properties, other characteristics may be present in a new compound and tests designed to evaluate these properties should be done.

For several years in our laboratories efforts have been directed toward the development of a general household antiseptic. The final formula contained a variety of pharmaceutical compounds along with the quaternary ammonium compound, di-isobutyl cresoxy ethoxy ethyl dimethyl benzyl ammonium chloride, as the antiseptic ingredient.

During the course of the development of the formula, antibacterial tests were chosen which unknowingly followed Salle's recommendations with some modifications.

The FDA Test for Liquid Antiseptics was used to determine the highest dilution of the antiseptic capable of killing *M. pyogenes* var. *aureus* in 10 but not 5 minutes. The inconsistencies that occur in phenol coefficient results on highly active quaternary ammonium compounds have been the subject of interest to investigators for several years. Inconstancy of the culture media, phospholipid content of peptones, mutation of the test organism, loop transfer method, agglutination of the bacteria, and bacteriostasis by the quaternary ammonium compounds have all been cited as being contributing factors to inconsistent end points in the test. Various modifications have been proposed to overcome some of these objections. Consequently, in our hands, the method was modified in that vigorous shaking prior to making each loop subculture of the medicant was done to reduce clumping and adherence of the bacteria to the side of the tube and a so-called T.A.T. broth, proposed by Armbruster and Ridenour (1), was used as a quaternary ammonium compound neutralizing subculture medium to overcome the bacteriostatic effect of the "quat." Only thru the use of these modifications and performance of the test many times were we able to eliminate "spotty" results and determine the highest dilution being bactericidal for *M. pyogenes* var. *aureus* and a variety of other organisms in 10 but not 5 minutes in the presence and absence of 10% serum at 20 and 37°C. Because of its relative simplicity and reproducibility in our hands, the method is now used in our laboratory as the primary bacteriological control test on newly manufactured lots of the antiseptic.

The Kolmer Bacteriostatic Test was employed to determine the extent of bacteriostasis. The test is extremely simple and yields sharply defined results. It determines the highest dilution of a disinfectant capable of restraining the growth of the test organism for a stated period of time and is of particular value for comparing the antiseptic properties of various chemical agents. At the end of a given period of time, the tubes may be subcultured onto a solid medium to determine whether the organisms have been killed or merely restrained. In this manner, a bactericidal test is also conducted.

To determine the speed of action, a so-called "percentage-kill" test was done. Briefly, this involved a mixing of the test organism and antiseptic in a special mixing apparatus. At various intervals of from 1 to 10 minutes, samples were removed and pour plates made from which the number of surviving bacteria was determined. The number of surviving organisms was then plotted against time of exposure to

the antiseptic to determine the number of organisms killed per unit of time.

Although agar-plate or cylinder-plate methods of testing have been widely used with chemotherapeutic agents, these methods of testing for bactericidal activity have not been found to be applicable to quaternary ammonium compound testing, possibly due to the inability of ionic aggregates to pass through the agar network or due to physical adsorption of the cationic compounds on the agar. However, the methods are useful in that a comparative penetrability of various quaternary ammonium compounds through agar may be determined. Therefore, the penetrability of the antiseptic, not the bactericidal activity, was determined by the Filter Paper Disc Method.

Chronic and acute toxicity studies carried out by another department of the laboratory by standard pharmacological methods, and tests made on exposed areas of skin which revealed no demonstrable cutaneous reactions indicated the low order of toxicity of the formula.

Consequently, from the results of these tests, we knew the highest dilution of the formula capable of killing *M. pyogenes* var. *aureus* and other organisms in 10 but not 5 minutes; we knew the extent of bacteriostasis of the antiseptic; we knew the speed of action; we knew the effect of organic matter and temperature upon the activity of the germicide; we knew its penetrability on agar as compared to similar compounds; and finally we knew that it was relatively non-toxic.

Inasmuch as each of these tests measures only one specific property of antiseptics, the results, when considered individually, tell little or nothing concerning the activity of an antiseptic. In fact, the evaluation of an antiseptic on the basis of any single one of these tests alone may easily prove to be an embarrassing and costly error. It is only when considered collectively that the results assume a significant meaning insofar as the overall activity of the newly-developed antiseptic is concerned.

With these basic characteristics determined, additional properties that the newly-developed antiseptic may be suspected of possessing can be evaluated. For our specific antiseptic, there were several. It was desirable to know the effect of the formula upon various contaminated objects such as wood, cloth, instruments, skin and the like.

Since the general trend in antiseptic testing today favors tests which more accurately simulate conditions of actual use of the germicide, laborious and time-consuming tests were employed to evaluate these properties under as closely simulated conditions of use as laboratory facilities would permit.

The results of these tests indicated that this specific antiseptic formula was highly effective on cloth, wood, instruments and skin. It was also demonstrated that a considerable amount of residual antibacterial activity was bestowed by the antiseptic onto cloth and skin and presumably onto other surfaces. Various other types of in *vitro* and in *vivo* tests were also performed which gave confirmatory or incidental information relative to the activity of the antiseptic.

Consequently, then, the collective results of all these various tests gave us a comparatively clear picture of the antibacterial activity of the antiseptic formula developed in our laboratory—a picture from which we could intelligently predict the practical value of the germicide—a picture which no one single antiseptic test could give us, and the clinical use of this antiseptic thus far has borne out our predictions extremely well.

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BOTANY

Chairman: M. S. MARKLE, Earlham College

William Gambill, Wabash College, was elected chairman for 1951.

ABSTRACTS

Vegetative morphology and anatomy of Cacao, *(Theobroma cacao* L.). ERWIN R. BROOKS, Purdue University.—Cacao, the source of chocolate, is a small evergreen tree, native to the american tropics. It is of special morphological interest due to its dimorphic shoot, chupon and orqueta formation, the occurrence of flowering cushions on the main trunk, and the basal and apical pulvini on the leaf petioles.

The main stem terminates in a five branched orqueta. These five branches differ morphologically from the main stem and chupons in that the branches have a phyllotaxy of 1/2 while the main trunk and chupons have a 3/8 phyllotaxy. Only chupons are produced on the trunk below the orqueta. Some chupons are formed on the branches, usually after injury or pruning. The chupons again terminate in a five-branch orqueta.

One of the most interesting anatomical features is the abundance of mucilaginous material throughout the plant. It occurs as single cell strands in the root tip and fills occasional cells and in the more mature root. In the stem it is found in the pith and cortex in lysigenous cavities.

The metaxylem of the primary root is hexarch and that of the secondary or lateral roots is tetrarch. However, the main trunk, chupons, and branches are anatomically similar. Anatomical examination of the five-branched orqueta shows a lack of internode elongation between the branches.

There is only one bud to a leaf axil. This bud may form a branch or a flowering cushion. The flowering branch is dichotomous and rudimentary except for the terminal internode and the pedicels.

Regular, brick-shaped, cortical cells, which contain very small starch granules, appear to be responsible for movement in the pulvini.

A technique for the study of *Oenothera* chromosome morphology. CATHERINE GARDELLA and RUBY VALENCIA.—Although *Oenothera* has been studied genetically and cytologically for a considerable number of years, little is known regarding the morphology of *Oenothera* chromosomes. This is due to the small size and difficulty of staining mitotic chromosomes of this plant. A technique is described which has been used to study the morphology of chromosomes of the generative cell in pollen tubes grown *in vitro*. These chromosomes are larger than those in other mitotic cells. An additional advantage is the fact that the

nucleus is haploid. This makes possible, with the selection of suitable plant material, the analysis of chromosome morphology of the different complexes found in *Oenothera* races.

The action of certain inhibitors upon the respiration of excised maize roots. RAYMOND E. GIRTON, Purdue University.—The influence of certain respiratory inhibitors on the O_2 consumption of detached, sterile, primary roots of germinating hybrid maize grains was studied. Both cyanide and azide resulted in rapid and marked inhibitions of respiration. Using M/1000 concentrations, 50% and 40 % inhibitions respectively were obtained followed by apparent recovery. The copper inhibitor, potassium ethyl xanthate, in M/1000 concentration produced no inhibition even when a second addition was made. The iron inhibitor o-phenanthroline, however, at M/1000 concentration produced a gradually increasing inhibition amounting to approximately 75% in 19 hours. This effect was obtained at both pH 5.8 and pH 7.6.

The occurrence of the genus *Callixylon* in the Lower Mississippian. J. H. HOSKINS, University of Cincinnati, and A. T. CROSS, University of W. Va.—*Callixylon* is a well known genus of the family Pityeae of the order Cordaitales, its several species ranging essentially throughout the vertical range of the Upper Devonian to the extent that the genus has been considered a fairly reliable indicator of rocks of that age. The best known species, *Callixylon Newberryi*, common in the black shales of Indiana, Ohio and Kentucky, is apparently restricted to a single upper Devonian horizon. Studies of phosphatic petrifactions from the basal Mississippian of Indiana, Kentucky and Illinois indicates that *Callixylon* is represented in these younger beds by more than one new species. This conclusion is based primarily on the occurrence in radial sections of secondary wood of a radial alignment of discontinuous pit groups, characteristic insofar as known, of but the single genus *Callixylon*.

An anatomical study of the roots of seedlings of *Smilax hispida* Muhl. FANNIE MAE HURST, Purdue University.—Seedlings which were collected near Lafayette, Indiana, were used in an anatomical study of this species of *Smilax*. Preliminary investigation of the roots showed that some of these possessed few xylem strands and no pith instead of a polyarch siphonostele which is considered characteristic of *Smilax*. This condition has been found and further studied in greenhouse seedlings. The seed were successfully germinated after a 60 day period of low-temperature stratification.

The *in vitro* effect of various forms and concentrations of nitrogen on the morphology of *Verticillium albo-atrum* R. et B. ROBERT L. JOHNSON, Purdue University.—*Verticillium albo-atrum* has an extremely wide host range and when cultured under varying environmental conditions is apt to present misleading morphological characteristics.

When the nitrogenous constituent of a synthetic medium was manipulated in both form and concentration the appearance of the fungal

mat was also changed. The use of peptone, urea, ammonia, nitrate and nitrite at equivalent concentrations of nitrogen presented growths ranging from a white floccose pellicle to a black carbonaceous appearing type of colony. Growth also ranged from floating to submerged.

Such evidence indicates that extreme caution in the selection of a cultural medium is necessary before a positive identification of the organism can be made. Standardization of the cultural medium is also recommended as a means of preventing species nomenclature which is not warranted.

Attempts at isolating *Verticillium albo-atrum B11B* from the soil. J. V. LUCK, *Purdue University.*—Information about the survival in the soil of the fungus *Verticillium albo-atrum,* B11B which causes a serious wilt disease of *Mentha piperita L.* is important since methods of control of the disease must be directed at the fungus. Resistant cross breeds of this male sterile mint plant have been developed, but the oil is not acceptable.

The soil dilution plate method rather than the host indicator plant method was used to index the degree of soil infestation. The problem here consisted in finding a cultural medium upon which *Verticillium* would not be crowded out by the more rapidly growing molds of the muck soils. Different inhibitive agents including penicillin, streptomycin, crystal violet and oxgall were used in preparing the isolation media. In addition, different concentrations and combinations of several minor elements were used as inhibitory agents.

The chances of obtaining *Verticillium* from the soil were greatly enhanced by the presence of plant debris in the soil sample.

As far as methods are concerned, the best results were obtained by flooding with soil dilutions the surfaces of previously poured plates of Czapeks medium which contained antibiotics.

Vascular Flora of the Recently Acquired Ross Biological Reserve. CHESTER W. MILLER, Purdue University.—A preliminary inventory of the vascular vegetation of the Ross Biological Reserve is nearing completion. In this report, the system of classification used is that of Engler and Prantl. This survey thus far shows a total of 84 families, 222 genera, 353 species, 31 varieties, and 5 forms. The division Pteridophyta is represented by two species of class Articulatae and eight species of two families of class Filicinae; division Spermatophyta by 343 species from 81 families; subdivision Gymnospermae by a single species, *Juniperus virginiana* L.; subdivision Angiospermae by 80 families, 213 genera, 342 species, 31 varieties, and 5 forms; 60 species, 3 varieties, and 2 forms of which represent 39 genera from nine families of the class Monocotyledoneae; 282 species, 28 varieties, and 3 forms represent 174 genera from 71 families of the class Dicotyledoneae. In the class Dicotyledoneae, 49 species are trees, 16 are shrubs, and 314 are herbs. The families most abundantly represented in order of their abundance are: Compositae—46 species, Graminae—32 species, Leguminosae—22 species, Rosaceae—18 species, Labiatae—14 species, and Lilia-

ceae—12 species. There are 46 families represented by a single genus 36 of which are represented by a single species.

Since protection from grazing was put in effect just before this study began, the inventory will be of value for future comparisons.

Present status of botanical and agricultural research in India. C. MERVIN PALMER, Cincinnati, Ohio.—A number of agricultural colleges and experiment stations as well as botanical laboratories were visited by the writer during 1947-1949. In part this was done under the auspices of the UNESCO Science Cooperation Office for South Asia. Institutions visited included the Indian Agricultural Institute at Delhi, the cereal rust laboratories at Simla and Agra, the Gandhian agricultural center at Sevagram, the paleobotanical Institute at Lucknow, the botanical gardens at Calcutta and Ootacamund, and the agricultural experiment stations at Kanpur, Allahabad, Coimbatore, Agra, Coonoor, Trivandrum, Nagpur, Kalimpong and Bangalore.

In botany the emphasis has been on work in the fields of morphology, paleobotany, phycology and economic botany. Widespread interest in taxonomy is hampered by lack of available manuals, while physiology is retarded by lack of laboratory equipment. Encouragement is being given to agricultural research as a part of the program to make India self sufficient in food stuffs. The great majority of the scientific laboratories are sponsored by the central or provincial governments.

Interest is high in the various scientific societies, such as the All India Science Congress, the Indian Academy of Science, the Indian Botanical Society and the Botanical Society of Bengal.

The Beech line in Northwestern Indiana. J. E. POTZGER and CARL O. KELLER, Butler University.—The westward extension of beech was determined on basis of survey records from the original U. S. Land survey. The border line is approximately crescent-shaped running from Porter County in the north to Warren County. The counties where beech disappeared are Porter, LaPorte, Marshall, Fulton, Cass, Carroll, Tippecanoe, Fountain and Warren. Percentage abundance of beech decreases progressively as one compares ranges of townships from east to west. In Warren County only three southern townships had beech.

Forest and prairie in three Northwestern Indiana Counties. FRED W. ROHR and J. E. POTZGER, Butler University.—The original vegetation of Lake, Jasper and Newton counties was reconstructed from the survey records of the original U. S. Land Survey field notes. Prairie conditions were expressed as wet, or dry prairies and oak openings. Central Lake County was wet prairie while southern portions of Jasper and Newton counties were dry prairie. The trees recorded in Jasper and Newton counties were primarily species of oak while in Lake county there was an oak-hickory association.

Chromosome numbers in *Claytonia*. NORMAL ROTHWELL and C. B. HEISER, Jr., Indiana University.—Chromosome counts for the genus *Claytonia* have not previously been published. Counts of n=8 have been

obtained for *C. lanceolata* from Colorado, *C. rosea* from Arizona, and *C. caroliniana* from Montreal. *Claytonia virginica* has been found to include both diploid (n=8, from Iowa, Wisconsin, Indiana, Ohio, and Kentucky) and tetraploid (n=16, from Missouri, Indiana, Pennsylvania, and Ohio) races. Although much morphological overlapping between the two races occurs, preliminary comparisons indicate that "giant" forms are more frequent and that pollen is slightly larger in the tetraploids. Great diversity in *C. virginica* exists in Indiana and this region should furnish rich material for the study of variation in this species.

Microclimates of four adjacent areas in the chaparral of San Dimas Canyon, California. C. FRANCIS SHUTTS, Purdue University.—The microclimates of a grass meadow, scrub oak-toyon chaparral, coastal sage, and chamise chaparral in San Dimas Canyon, California, were investigated from April 1 to July 28, 1950. A control climatic station for correlating data to weather records, and five field stations consisting of Six's type air thermometers at three inches and five feet heights, Six's type soil thermometers at one-half inch and six and one-half inches depths, and paired white and black spherical atmometers were maintained at the site. In addition, soil moisture determinations were made periodically. The data indicate that "frost pockets" may be formed through the restriction of air movement by dense vegetation; that the decrease of air temperature means with increase in height above the ground may be reduced by vegetation; that the seasonal changes in the angle of insolation causes a greater seasonal variation of soil temperature and evaporation on north slopes than on south slopes, suggesting that the more rigorous soil conditions of south slopes may be due to a longer period of severe insolation; and that the determination of vegetative climaxes in southern California is due principally to the soil moisture factor.

***Tragopogon* in Indiana.** DALE M. SMITH, Purdue University.—The three introduced Goat's Beards, *Tragopogon porrifolius, T. pratensis,* and *T. dubius,* are becoming common in central Indiana. Several anomalous specimens were found during the early summer of 1950. Evidence from morphological characters and pollen fertility studies indicates that some of these plants are hybrids of *T. porrifolius* x *T. pratensis.* A key to the species is given which is based on achene characters. New county records are reported for the species and the hybrid.

Indiana Plant Distribution Records, XI. 1950

Genera are listed in the order used in Deam: Flora of Indiana and species are given alphabetically within the genera. Symbols following the county in which specimens were collected indicate the herbaria in which confirming specimens have been deposited. Entities listed for the first time are given in bold face followed by literature references and name of collector.

The specimens listed below have been collected by the following collectors: Ball State Teachers College (BS): Mrs. Marian Rector; Butler University (B): J. S. Brooks, R. C. Friesner, Johanna Jones, Jack McCormick, and J. E. Potzger; Chicago Natural History Museum (F); Mr. Brady; Deam Herbarium (D): E. S. Bastian, C. C. Deam, E. J. Hill, Clarence Swink, F. A. Swink, and Mr. Wessin; DePauw University (DP): John H. Coats and Winona H. Welch; Indiana University (IU): J. S. Brooks, Raymond Blunk, Franklin Buser, Morris S. Clark, Joseph Craig, Charles B. Heiser, Jr., William M. Johnson, William Quinn, Helen Reed, John L. Ricketts, Lillie Riley, Dale M. Smith, Paul Weatherwax, and E. Nolan Wells; Wabash College (W): A. R. Bechtel, Dr. A. Clapp, D. B. Ward, and A. R. Young.

The committee maintains a card file showing published distribution of each species within the state. Botanical workers needing such information may obtain distribution maps of any species recorded in the Flora, or subsequently added in these reports, by requesting same from the secretary of this committee.

Species

Botrychium dissectum, Decatur (B), Fountain (B), Franklin (B). *B. d.* v. *obliquum*, Fountain (B). *Cystopteris fragilis* v. *protrusa*, Washington (IU). *Onoclea sensibilis*, Pulaski (B). *Polystichum acrostichoides* f. *incisum*, Ripley (B). *Athyrium filix-foemina* v. *asplenioides*, Fountain (B). *Asplenium platyneuron*, Decatur (B). *Adiantum pedatum*, Dearborn (B). *Azolla caroliniana*, Starke (D). *Equisetum arvense*, Washington (IU). *E. prelatum*, Orange (IU), Washington (IU). *Taxus canadensis*, Fountain (B). *Pinus strobus*, Parke (B).

Typha angustifolia, Carroll (IU). *Sparganium chlorocarpum*, Jay (IU). *Sagittaria brevirostra*, Washington (IU). *Arundinaria gigantea*, Scott (IU). *Bromus commutatus*, Lagrange (IU). *B. tectorum*, Parke (B). *Festuca rubra*, Monroe (IU). *Poa pratensis*, Fountain (B), Greene (IU). *Eragrostis cilianensis*, Fountain (B), Parke (B). *E. frankii*, Daviess (B). *Uniola latifolia*, Marion (B), Parke (B). *Dactylis glomerata*, Greene (IU), Ripley (B). *Elymus virginicus*, Parke (B). *Hystrix patula* v. *bigeloviana*, Montgomery (B), Parke (B). *Hordeum jubatum*, Lagrange (IU), Parke (B). *H. pusillum*, Greene (IU).

Sphenopholis nitida, Greene (IU). *Agrostis elliottiana,* Greene (IU). *A. palustris,* Jefferson (IU). *Phleum pratense,* Dearborn (B). *Muhlenbergia schreberi,* Montgomery (B). *M. sobolifera,* Parke (B). *M. teniuflora,* Parke (B). *Sporobolus asper,* Marshall (D). *Aristida oligantha,* Fountain (B), Montgomery (B), Parke (B). *Eleusine indica,* Fountain (B). *Leersia virginica,* Fountain (B). *Digitaria sanquinalis,* Fountain (B). *Paspalum publiflorum* v. *glabrum,* Harrison (B). *Panicum philadelphicum,* Montgomery (B). *P. stipitatum,* Decatur (B), Switzerland (B). *Echinochloa crusgalli,* Switzerland (B). *Setaria lutescens,* Dearborn (B). *Andropogon elliottii,* Ripley (B). *A. virginicus,* Porter (D).

Carex plantaginea, Monroe (IU). *C. tenera,* Porter (D). *Acorus calamus,* Monroe (IU), Morgan (IU), Owen (IU). *Arisaema atrorubens* f. *viride,* Fayette (B). *A. a.* f. *zebrina,* Decatur (B). *A. triphyllum* f. *pusillum,* Crawford (B), Delaware (B), Jennings (B). *Lemna minor,* Elkhart (IU). *L. trisulca,* La Porte (IU). *Commelina communis,* Marion (B), Montgomery (B,W). *Tradescantia subaspera,* Delaware (BS), Ripley (B). *Juncus canadensis,* Ripley (B). **J. militaris** Bigel. Gray Man. 8 ed. p. 414. Britton and Brown Ill. Fl. 2 ed. p. 477. Porter (D). Collected by F. A. and Clarence Swink.

Allium canadense, Hamilton (B). *A. cernuum,* Ripley (B). *A. tricoccum,* Delaware (BS). *A. vineale,* Dearborn (B), Ripley (B). *Erythronium albidum,* Clark (IU), Jackson (IU), Owen (IU). *E. americanum,* Washington (IU). *Camassia scillioides,* Fayette (B). *Ornithogalum umbellatum,* Monroe (IU). *Smilacina racemosa* v. *cylindrata,* Cass (B). *Asparagus officinalis,* Parke (B). *Maianthemum canadense,* Montgomery (W). *Polygonatum canaliculatum,* Montgomery (B). *P. pubescens,* Decatur (B). *Trillium grandiflorum,* Monroe (IU). *T. sessile,* Owen (IU). *Smilax glauca* v. *genuina,* Dearborn (B), Ripley (B). *S. g.* v. *lasioneura,* Ohio (B).

Dioscorea villosa, Dearborn (B). *Iris virginica* var. *shrevei,* Owen (IU). *Orchis spectabilis,* Delaware (BS), Hamilton (B). *Habenaria lacera,* Lake (D). *H. viridis* v. *bracteata,* Lake (D). *Spiranthes cernua,* Montgomery (B). *S. gracilis,* Cass (B), Fountain (B). *S. ovalis,* Ripley (B). *Goodyera pubescens,* Fountain (B). *Corallorhiza maculata,* Lake (D). *C. wisteriana,* Putnam (DP), Ripley (B). **Malaxis brachypoda** (Gray) Fern. Gray Man. 8 ed. p. 485. Floyd (W). Collected in 1836 by Dr. A. Clapp. See Flora p. 1038.

Populus grandidentata, Decatur (B), Parke (B). *P. heterophylla,* Dubois (IU). *Salix amygdaloides,* Monroe (IU). *S. glaucophylla,* Newton (B). *S. nigra,* Switzerland (B). *S. sericea,* Ripley (B). *Juglans cinerea,* Fountain (B). *J. nigra,* Fountain (B), Parke (B), Ripley (B), Washington (IU). *Carya cordiformis* v. *latifolia,* Posey (D). *C. illinoensis,* Daviess (B). *C. ovata,* LaGrange (IU), Switzerland (B). *C. pallida,* Daviess (B). *C. texana* v. *arkansana,* Gibson (D). *Carpinus caroliniana* v. *virginiana,* Ripley (B). *Ostrya virginiana* v. *glandulosa,* Dearborn (B), Parke (B).

Quercus alba f. *latiloba,* Crawford (B), Harrison (B), Ripley (B). *Q. bicolor,* Parke (B), Ripley (B), Switzerland (B). *Q. borealis* v. *maxima,* Fountain (B), Lagrange (IU). *Q. imbricarcia,* Dearborn (B). *Q. macrocarpa,* Rush (B). **XQ. paleolithicola** Trel. Mem. Natl. Acad. Sci. 20:16. 1924. Jour. Arnold Arboret. 29:36-37. 1948. Elkhart (D), Lagrange (D). Collected by Charles C. Deam and Ralph Kriebel. *Q. palustris,* Marshall (D), Switzerland (B). **XQ. runcinata,** Gibson (K), Lawrence (K). **XQ. saulii** Schneider. Sargent Silva 8: pl. 361. Gray Man. 8 ed. p. 543. Clark (D). Collected by C. C. Deam and Dan Den Uyl. *Q. stellata,* Washington (IU). **XQ. tridentata** Engelm. Sargent Silva 8: pl. 433. Britton & Brown Ill. Fl. 2ed. 1:622. Crawford (B,D). Collected by Ray C. Friesner.

Ulmus americana f. *alba,* Fountain (B), Montgomery (B). *U. a.* f. *laevior,* Fountain (B), Parke (B). *U. a.* f. *pendula,* Huntington (D). *U. rubra,* Ripley (B). *Celtis occidentalis,* Daviess (B), Perry (D), Switzerland (B). *C. o.* v. *canina,* Perry (D), Pulaski (D). **C. tenuifolia** v. **georgiana,** (Small) Fern & Schub. Gray Man. 8 ed. p. 554. Daviess (B), Harrison (B,D). Collected by Charles C. Deam and R. C. Friesner. *Morus alba* v. *tatarica,* Montgomery (B,W). *Maclura pomifera,* Carroll (IU). *Cannabis sativa,* Fayette (IU). *Laportea canadensis,* Montgomery (W). **Asarum canadense v. acuminatum** Ashe. Gray Man. 8 ed. p. 563. Britton & Brown Ill. Fl. 2 ed. 1:642. Jefferson (B) Collected by R. C. Friesner. *A. reflexum,* Fayette (B), Ripley (B).

Rumex acetosella, Owen (B), Switzerland (B). *R. crispus,* Fountain (B), Parke (B). *R. obtusifolius,* Montgomery (B), Parke (B). *Polygonum hydropiper* v. *projectum,* Cass (B). *P. hydropiperoides* f. *strigosum,* Starke (B). *P. pennsylvanicum* v. *laevigatum,* Fountain (B), Montgomery (B). *P. scandens,* Ripley (B). *Fagopyrum esculentum,* Porter (IU). *Cycloloma atriplicifolia,* Greene (IU).

Oxybaphus nyctagineus, Delaware (BS). *Phytolacca americana,* Vermillion (IU), Washington (IU). *Claytonia virginica,* Fayette (IU). *Stellaria longifolia,* Monroe (IU). *S. media,* Owen (IU). *Cerastium nutans,* Owen (IU). *C. vulgatum* v. *hirsutum,* Marion (B). *Arenaria serpyllifolia,* Putnam (DP). *Paronychia canadensis,* Brown (IU). *Silene cucubalus,* Hamilton (B). *S. stellata,* La Porte (IU), Porter (IU), Ripley (B), Washington (IU). *Lychnis alba,* Dearborn (B), Switzerland (B). *Dianthus armeria,* Lagrange (IU), Ohio (B). *Saponaria officinalis,* Dearborn (B), Pulaski (B), Switzerland (B), White (B).

Caltha palustris, Monroe (IU). *Isopyrum biternatum,* Fayette (IU). *Cimicifuga racemosa,* Dearborn (B), Ohio (B). *Aquilegia canadensis,* Decatur (B), Fayette (IU). *Delphinium ajacis,* Parke (B). *D. tricorne,* Ripley (B). *Anemone quinquefolia* v. *interior,* Decatur (B). *Anemonella thalictroides,* Fayette (B, IU). *Clematis viorna,* Ohio (B). *Ranunculus abortivus,* Fayette (B). **R. carolinianus** DC. Torr. Bot. Cl. Bull. 68:484. 1941. Putnam (B). Collected by R. C. Friesner, *R. hispidus,* Decatur (B). *Thalictrum dasycarpum,* Delaware (BS). *T. revolutum,* Dearborn

(B). *Podophyllum peltatum,* Fayette (B). *Jeffersonia diphylla,* Fayette (IU). *Liriodendron tulipifera,* Ripley (B). *Asimina triloba,* Parke (B), Pulaski (D), Switzerland (B).

Sassafras albidum, Fountain (B). *S. a.* v. *molle,* Fountain (B). *Sanguinaria canadensis,* Fayette (B). *Lepidium campestre,* Fayette (B). *Sisymbrium officinale* var. *leiocarpum,* Owen (B). Parke (B). *Brassica kaber* v. *pinnatifida,* Delaware (BS). *B. nigra,* Hamilton (IU), Owen (IU). *Rorippa sylvestris,* Ripley (B). *Nasturtium officinale,* Orange (IU), Owen (B). *Cardamine bulbosa,* Delaware (BS), Owen (IU), *C. douglassii,* Fayette (IU). *C. pennsylvanica,* Decatur (B), Fayette (IU). *Dentaria heterophylla,* Decatur (B). *D. laciniata,* Fayette (IU). *Capsella bursa-pastoris,* Dearborn (B), Fayette (B). *Draba reptans,* Cass (B). *D. verna,* Fayette (B, IU), Jennings (B). *Arabis canadensis,* Lake (D). *A. laevigata,* Decatur (B).

Penthorum sedioides, Morgan (IU), Washington (IU). *Heuchera americana* v. *brevipetala,* Dearborn (B). *Grossularia missouriensis,* Montgomery (W). *Liquidambar styraciflua,* Switzerland (B). *Spiraea alba,* Carroll (IU). *Aronia prunifolia,* Decatur (B). *Fragaria virginiana,* Owen (IU). *F. v.* v. *illinoiesnsis,* Ripley (B). *Duchesne indica,* Decatur (IU). *Potentilla monspeliensis,* Fountain (B), Ripley (B), Switzerland (B), Washington (IU). *P. recta,* Fountain (B), Montgomery (B), Parke (B). *Geum vernum,* Fayette (IU). *Agrimonia pubescens,* Fountain (B), Ohio (B). *Rosa carolina,* Switzerland (B). *R. palustris,* Decatur (B), Fountain (B). *R. setigera* v. *tomentosa,* Parke (B). *Prunus virginiana,* Decatur (B).

Gleditsia triacanthos, Parke (B). *Gymnocladus dioica,* Pulaski (B). *Baptisia leucantha,* Pulaski (B). *Medicago sativa,* Fountain (B). *Melilotus alba,* Pulaski (B), Starke (B), Washington (IU). *Trifolium arvense,* Lagrange (IU). *T. pratense,* Parke (B), Lagrange (IU). **T. pratense f. leucochraceum** Aschers & Prantl. Gray Man. 8 ed. p. 893. Parke (B). Collected by Jack McCormick. *T. procumbens,* Ripley (B), Switzerland (B). *T. repens,* Fountain (B), Lagrange (IU). *Robinia pseudo-acaccia,* Fountain (B). *Lespedeza procumbens,* Ripley (B). *Vicia villosa,* Fayette (IU), Montgomery (W), Washington (IU). *Amphicarpa bracteata,* Ohio (B). *A. b.* v. *comosa,* Fountain (B). *Apios americana,* Decatur (B), Elkhart (IU), Ripley (B).

Oxalis europaea, Fountain (B). *O. e.* v. *bushii* f. *subglabrata,* Montgomery (B). *O. e.* v. *bushii* f. *vestita,* Owen (B). *O. e.* f. *cymosa,* Dearborn (B), Fountain (B). *O. grandis,* Ohio (B). *O. stricta,* Parke (B). *O. violacea,* Fayette (B), Ohio (B). *Linum medium* v. *texanum,* Ripley (B). *L. striatum,* Decatur (B). *L. virgnianum,* Dearborn (B). *Zanthoxylem americanum,* Washington (IU). *Ptelea trifoliata,* Owen (IU). *Polygala ambigua,* Switzerland (B). *P. sanguinea,* Decatur (B), Fountain (B). *P. senega,* Washington (IU). *Croton monanthogynus,* Dearborn (B). *Euphorbia corollata,* Parke (B). *E. dentata,* Steuben (D). *E. maculata,* Clark (B), Dearborn (B). *E. marginata,* Morgan (IU).

Rhus aromatica, Fayette (IU). *R. copallina* v. *latifolia*, Dearborn (B). *R. typhina*, Fountain (B). *Ilex verticillata*, Dubois (IU). *Staphylea trifolia*, Fayette (B), Parke (B). *Acer negundo*, Carroll (IU). *A. nigrum*, Switzerland (B). *A. saccharinum*, Switzerland (B). *Aesculus glabra*, Carroll (IU), Parke (B), Pulaski (D), Switzerland (B). *Impatiens biflora*, Fayette (IU), Fountain (B). *I. pallida*, Switzerland (B). *Vitis labrusca*, Decatur (B). *V. vulpina*, Lagrange (IU). *Parthenocissus quinquefolia*, Carroll (IU). *Tilia americana*, Dubois (IU).

Abutilon theophrasti, Fountain (B), Hendricks (B), Marion (B), Montgomery (B), Parke (B). *Malva neglecta*, Parke (B), Fountain (B). *Sida spinosa*, Fountain (B). *Hibiscus trionum*, Parke (B). *Hypericum canadense*, Lake (D). *H. perforatum*, Decatur (B), Switzerland (B). *H. prolificum*, Ripley (B). *H. punctatum*, Decatur (B), Fountain (B), La Porte (IU). *H. virginicum*, Lake (D). *Hybanthus concolor*, Ripley (B). *Viola eriocarpa* f. *leiocarpa*, Delaware (BS), Ripley (B). *V. kitaibeliana* v. *rafinesqui*, Montgomery (W). *V. papilionacea*, Delaware (BS). *V. striata*, Decatur (B), Delaware (BS), Fayette (B). *V. triloba*, Fayette (B).

Opuntia humifusa, Gibson (IU). *Jussiaea diffusa*, Marion (B). *Ludwigia palustris* v. *americana*, Cass (B), Ripley (B). *Epilobium coloratum*, Fountain (B). *Oenothera laciniata*, Cass (B). *Oe. pycnocarpa*, Switzerland (B). *Circaea quadrisulcata* v. *canadensis*, Dearborn (B), Switzerland (B). *Panax quinquefolius*, Fayette (B). *Hydrocotyle umbellata*, Elkhart (IU). *Sanicula canadensis* v. *grandis*, Ohio (B). *S. c.* v. *typica*, Daviess (B), Hamilton (B). *Osmorhiza claytoni*, Brown (IU), Dearborn (B). *Erigenia bulbosa*, Fayette (IU). *Zizia aurea*, Montgomery (W). *Cicuta maculata*, Dearborn (B). *C. maculata*, Pulaski (B). *Perideridea americana*, Lake (D). *Pastinaca sativa*, Carroll (IU), Fountain (B). *Heracleum lanatum*, La Porte (IU), Marion (B). *Daucus carota*, Carroll (IU), Fountain (B), Pulaski (B), Tippecanoe (B), Starke (B), Switzerland (B), White (B). **D. c. f. epurpuratus** Farwell. Gray Man. 8ed. p. 1104. Fountain (B). **D. c. f. roseus**, Montgomery (B,W). See Flora, p. 728.

Nyssa sylvatica v. *caroliniana*, Dearborn (B). *Cornus racemosa*, Decatur (B). *Monotropa uniflora*, Fountain (B). *Gaylussacia baccata*, Parke (B). *Samolus parviflorus*, Dearborn (B). *Lysimachia ciliata*, Washington (IU). *L. lanceolata*, Newton (B), Washington (IU). *L. quadrifolia*, Dearborn (B). *L. terrestris*, Lagrange (IU). *Dodecatheon meadia*, Fayette (IU). *Diospyros virginiana*, Vermillion (IU). *Fraxinus americana*, Fountain (B). *F. lanceolata*, Decatur (B), De Kalb (D), Pulaski (D), Washington (IU). *F. pennsylvanica*, Washington (IU), Wells (D). *F. nigra*, Fountain (B). *F. quadrangulata*, Pulaski (D), Washington (IU).

Sabatia angularis, Dearborn (B). *Gentiana andrewsii*, Ripley (B). *Frasera carolinensis*, Dearborn (B), Washington (IU). *Apocynum cannabinum*, Dearborn (B), Fayette (IU). *A. sibiricum*, Dearborn (B).

Asclepias purpurascens, Washington (IU). *A. quadrifolia,* Hamilton (B). *A. syriaca,* Fountain (B), Parke (B), Switzerland (B). **A. s. v. kansana** (Vail). Palmer & Steyermark. Gray Man. 8 ed. p. 1174. La Porte (D). Collected by F. A. Swink. **A. s. f. leucantha** Dore. Gray Man. 8 ed. p. 1174. Fountain (B). Collected by Jack McCormick. *A. tuberosa,* Carroll (IU), Dearborn (B), Montgomery (B). *A. verticillata,* Carroll (IU), Fountain (B). *Convolvulus arvensis,* La Porte (IU). *S. sepium,* Morgan (IU). *C. s. v. fraterniflorus, Dearborn* (B). *Ipomoea hederacea,* Fountain (B). *I. pandurata,* La Porte (IU), Washington (IU). *I. purpurea,* Dearborn (B).

Phlox paniculata, Ripley (B). *Hydrophyllum macrophyllum,* Orange (IU). *Phacelia purshii,* Monroe (IU). *Hackelia virginiana,* Delaware (BS), Fountain (B). *Myosotis scirpioides,* La Porte (IU). *Mertensia virginica,* Brown (B), Owen (IU). *Lithospermum arvense,* Lake (D), Lawrence (D). *Echium vulgare,* Dearborn (B). *Verbena hastata,* Parke (B). V. *simplex,* Washington (IU). *V. urticifolia,* Fountain (B), Switzerland (B), Washington (IU). *V. u. f. leiocarpa,* Delaware (BS). *Phyla lanceolata,* Ripley (B).

Teucrium canadense, Washington (IU). *T. c.* v. *virginicum,* Dearborn (B), Switzerland (B). *Scutellaria galericulata,* Decatur (B). *Agastache scrophulariaefolia,* Daviess (B), Dearborn (B). *Nepeta cataria,* Fayette (IU). *Glecoma hederacea,* Putnam (DP), Ripley (B,D). *G. h.* v. *parviflora,* Owen (IU). *Prunella vulgaris* v. *lanceolata,* Fountain (B). *Lamium purpureum,* Franklin (IU). *Leonurus cardiaca,* Fayette (IU). *Stachys paulstris* v. *homotrichia,* Carroll (IU). *S. riddellii,* Ripley (B). *S. tenuifolia,* Switzerland (B). *Monarda clinopodia,* Dearborn (B). *Blephilia hirsuta,* Ripley (B). *Lycopus uniflorus,* Ripley (B).

Mentha arvensis v. *typica* f. **glabra** (Benth.) Stewart. Rhodora 46:331. Gray Man. 8 ed. p. 1250. Jasper (B), Vermillion (B). Collected by R. C. Friesner. *M. a.* v. **villosa f. glabrata** (Benth.) Stewart. Rhodora 46:331. Gray Man. 8 ed. p. 1250. Harrison (B), Jennings (B). *M. a.* v. **villosa** f. **typica** Stewart. Rhodora 46:331. Gray Man. 8 ed. p. 1250. Randolph (B). *M. gentilis,* Ripley (B). *M. spicata,* Morgan (IU). *Collinsonia canadensis,* Fountain (B). *Nicandra physalodes,* Fayette (IU). *Lycium halimifolium,* Marion (B). *Physalis heterophylla,* Monroe (IU), Switzerland (B). *P. subglabrata,* Fountain (B). *Solanum rostratum,* Lagrange (IU). *Datura stramonium,* Fountain (B). *D. s.* v. *tatula,* Fountain (B).

Verbascum blattaria, Carroll (IU), Fayette (IU), Fountain (B), Pulaski (B), Switzerland (B). *V. b.* f. *albiflora,* Delaware (BS), Fountain (B). *V. thapsus,* Brown (IU), Carroll (IU), Dearborn (B), Fountain (B), Switzerland (B), Tippecanoe (B). *Scrophularia marilandica,* Fountain (B), Ohio (B), Parke (B). *Penstemon deamii,* Dearborn (B). *P. digitalis,* Dearborn (B). *Mimulus alatus,* Fountain (B). *Gratiola neglecta,* Switzerland (B). *Lindernia anagallidea,* Montgomery (B). *L. dubia* v. *typica,* Montgomery (B), Switzerland (B). *Gerardia*

tenuifolia v. *typica*, Ripley (B). *Campsis radicans*, Parke (B). *Martynia louisianica*, Montgomery (W). *Conopholis americana*, Decatur (B). *Orobanche uniflora* v. *typica*, Ripley (B). *Epifagus americana*, Decatur (B).

Plantago aristata, Pulaski (B), Switzerland (B). *P. lanceolata*, Fayette (B), Fountain (B). *P. rugelii*, Parke (B), Ripley (B). *Mitchella repens*, Fountain (B). *Galium concinnum*, Fountain (B). *G. obtusum*, Switzerland (B). *G. triflorum*, Fountain (B). *Viburnum rafinesquianum* (*V. affine* v. *hypomalacum* of Flora) Porter (D). Collected by E. S. Bastian in 1879. *Triosteum aurantiacum*, Dearborn (B). *T. a.* v. *glaucescens*, Fayette (IU). *Symphoricarpos orbiculatus*, Switzerland (B). *Lonicera dioica* v. *glaucescens*, Decatur (B). L. *japonica*, Ripley (B). *Valerianella intermedia*, Morgan (IU). *Valeriana pauciflora*, Fayette (IU). *Dipsacus sylvester*, Fountain (B), Marion (B). *Sicyos angulatus*, Fountain (B). *Specularia perfoliata*, Washington (IU). *Lobelia inflata*, Fountain (B).

Vernonia altissima, Decatur (B). *Eupatorium coelestinum*, Montgomery (B). *E. fistulosum*, Dearborn (B). *E. purpureum*, Lagrange (IU). *E. serotinum*, Fountain (B). *E. sessilifolium*, Daviess (B). *Kuhnia eupatorioides* v. *corymbulosa*, Tippecanoe (B). *Solidago canadensis* v. *gilvocanescens*, La Porte (B, IU). *S. erecta*, Franklin (B). *S. gigantea*, Cass (B). *S. g. v. leiophylla*, Ripley (B). *S. juncea*, Fountain (B), Noble (B, IU)), Switzerland (B). *S. latifolia*, Dearborn (B). X*S. ovata*, Harrison (B). *S. rigida*, Lagrange (B, IU). *S. rugosa*, Decatur (B). *S. rugosa* v. **villosa** (Pursh) Fern. Gray Man. 8 ed. p. 1407. Lagrange (B, IU). Collected by J. S. Brooks. *S. uliginosa* v. *levipes*, St. Joseph (B, IU). X*S. patuliginosa*, Henry (B).

Aster amethystinus, Tippecanoe (B). A. *cordifolius*, Harrison (B), Ohio (B). *A. paniculatus*, Brown (IU). *A. pilosus*, Switzerland (B). *A. prenanthoides*, Decatur (B). *A. sagittifolius*, Ohio (B). *A. shortii*, Ohio (B). *Erigeron annuus*, Fountain (B), Jay (IU), Switzerland (B). *E. canadensis*, St. Joseph (IU). *E. philadelphicus*, Fayette (B). *E. strigosus*, Fountain (B), Jay (IU), Switzerland (B). *Gnaphalium obtusifolium*, Fountain (B). *G. purpureum*, Switzerland (B). *Polymnia canadensis*, Ohio (B). *P. uvedalia*, Ohio (B). *P. u.* v. **densipilis** Blake. Rhodora 19:48. 1917. Gray Man. 8 ed. p. 1475. Gibson (D). Collected by Charles C. Deam.

Silphium laciniatum, La Porte (IU). *S. trifoliatum*, Monroe (IU). *Parthenium integrifolium*, Noble (F). *Ambrosia artimisiifolia* v. *elatior* f. *villosa*, Fountain (B), Marion (B), Parke (B). *Heliopsis helianthoides*, Fountain (B), La Porte (IU). Porter (IU). *Rudbeckia hirta*, Dearborn (B), Decatur (B). *R. laciniata*, St. Joseph (IU). *R. triloba*, Starke (IU). *Helianthus decapetalus*, Kosciusko (IU). *Actinomeris alternifolia*, Ohio (B), Washington (IU). *Coreopsis palmata*, Lagrange (IU). *C. tripteris*, Washington (IU). *Bidens bipannata*, Dearborn (B), Washington (IU). *B. cernua*, Monroe (IU), Morgan (B). *B. frondosa*,

Ohio (B). *Galinsoga ciliata,* Carroll (IU), Lagrange (IU), Montgomery (B, W), Switzerland (B).

Helenium autmnale, La Porte (IU). *H. nudiflorum,* Switzerland (B). *Anthemis cotula,* Boone (IU), Carroll (IU). *Achillea millefolium,* Owen (B). *A. m. f.* **rosea** Rand. & Redf. Gray Man. 8 ed. p. 1515. Montgomery (B,W). Collected by Jack McCormick. *Matricaria matricarioides,* Montgomery (B), Parke (B), White (B). *Chrysanthemum balsamita* v. *tanacetoides,* Lagrange (IU). *C. leucanthemum* v. *pinnatifidum,* Pulaski (B). *Artemisia annua,* Monroe (IU). *Erechtites hieracifolia,* Switzerland (B). *E. h.* v. **praealta** (Raf.) Fern. Gray Man. 8 ed. p. 1528. Fountain (B). Collected by Jack McCormick.

Cacalia atriplicifolia, Washington (IU). *Senecio obovatus,* Decatur (B). *Arctium minus,* Elkhart (IU), Fountain (B), Montgomery (W), Washington (IU). *A. m.* v. **pallidum** Farw. Gray Man. 8 ed. p. 1538. Parke (B). Collected by Jack McCormick. *Cirsium altissimum,* Parke (B), Washington (IU). *C. discolor,* Fountain (B). *C. vulgare,* Elkhart (IU), Fountain (B), Washington (IU). *Centaurea maculosa,* Jefferson (IU). *C. vochinensis,* Marion (B). *Cichorium intybus,* Carroll (IU), Dearborn (B), White (B).

Tragopogon major, Bartholomew (B), Brown (B), Cass (B), Clay (B), Clinton (B), Elkhart (B), De Kalb (B, D), Fountain (B, D), Franklin (B), Hancock (B, IU), Jasper (B, DP), Jefferson (IU), Kosciusko (B, D), Lagrange (B, D), Lake (B), La Porte (B), Madison (B), Marion (B, IU), Monroe (IU), Montgomery (B), Newton (DP), Noble (B), Porter (B, G), Pulaski (B), Putnam (B), Rush (B), Steuben (B, D), St. Joseph (B), Tippeconoe (B), Union (B), Wabash (B). *T. porrifolius,* Hancock (B, IU), Montgomery (B). *T. pratensis,* Hancock (IU), Montgomery (B), St. Joseph (B).

Taraxacum officinale, Fountain (B). *Sonchus arvensis* v. *glabrescens,* Porter (IU). *S. asper,* Washington (IU). *S. oleraceus,* Hamilton (IU), Marion (B). *Lactuca canadensis* v. *latifolia,* Tippecanoe (B). *L. floridana,* Fountain (B), Owen (B). *L. scariola,* Washington (IU). *Prenanthes altissima,* Ohio (B). *Hieracium scabrum,* Ripley (B).

Corrections

Holosteum umbellatum reported for Henry Co. in Plt. Distr. Records X should be Delaware (BS).

Helianthus silphioides Nutt. reported for Lawrence Co. in Plt. Distr. Records VII should be *H. laetiflolurs* v. **subrhomboidens** (Rydb). Fern. Rhodora 48:77-79. 1946. Gray Man. 8 ed. p. 1491.

Additional Species Added to the Deam Herbarium

The following species, previously reported in other herbaria, have been added to the Deam Herbarium.

Setaria viridis, Huntington. *Cyperus strigosus,* Huntington. *Ostrya*

virginiana, Huntington. *Fagus grandifolia,* Huntington. *Ulmus rubra,* De Kalb. *Celtis occidentalis* v. *crassifolia,* De Kalb. *C. o.* v. *canina,* Huntington. *Desmodium paniculatum,* Huntington. *Eurphorbia maculata,* Huntington. *Tilia americana,* Huntington. *Sida spinosa,* Huntington. *Fraxinus americana,* Huntington. *Scutellaria parvula* v. *leonardi,* Lake. *Prunella vulgaris* v. *lanceolata,* Huntington. *Physalis subglabrata,* Huntington. *Cirsium arvense,* Huntington.

State Flora Committee: CHARLES C. DEAM, Chairman
T. G. YUNKER
R. C. FRIESNER, Secretary

Higher Fungi of Marion County, Indiana

JOHN O. COTTINGHAM, Indianapolis

This, my fourth report of the "Higher Fungi of Marion County, Indiana," contains sixty species which makes a total of three hundred fifty-three species thus far found and identified. In addition to parties previously mentioned, I desire to give credit with thanks to the following persons who have assisted me in the search for fungi since my last report: Mesdames Hallie Bidgood, Helen Miller, Dolly M. Stuck and Messrs. Don Knight and Wesley Stockinger.

I have added F. J. Seaver to the list of authorities whose nomenclature I am following.

My thanks to Dr. Alexander H. Smith, who identified the rare *Rhodotus subpalmatus*. I have included *A. Caesarea* in order to place it on record as found in Indiana although it was found in Owen County.

Agaricaceae

Agaricus abruptibula Pk.
Amanita Caesarea Fr.
(McCormick's Creek State Park)
Amanita virosa Fr.
Cantharellus tubaeformis Fr.
Clitocybe catina Fr.
Clitocybe caespitosa Pk.
Clitocybe eccentrica Pk.
Clitocybe piccina Pk.
Clitocybe patuloides Pk.
Clitocybe laccata Fr.
Coprinus picaceus Fr.
Clitopilus undatus Fr.
Cortinarius autumnalis Pk.
Cortinarius michiganensis Kauff.
Eccilia carneo-grisea B & B
Entoloma scabrinellum Pk.
Galera tenera Fr.
Hebeloma mesophaeum Fr.
Hygrophorus miniatus Fr.
Hygrophorus pratensis Fr.
Inocybe rimosa Pk.
Lactarius hysginus Fr.
Lactarius pyrogalus Fr.
Leptonia asperella Fr.
Marasmius velutipes B & C
Mycena parabolica Fr.
Omphalia campanella Batsch
Pholiota luteofolia Pk.
Pluteus nanus Fr.
Pluteus salicinus Fr.
Rhodotus subpalmatus A. H. Smith
Russula aeruginea Lind.
Russula alutacea Fr.
Russula cyanoxantha Fr.

Polyporaceae

Boletus scaber Fr.
Boletus bicolor Pk.
Boletus badius Fr.
Boletus fumosipes Pk.
Polyporus obliquus Pers.
Polyporus robiniophilus Murr.
Polyporus zonatus Fr.

Clavariaceae

Clavaria vermicularis Fr.

Hydnaceae

Irpex lacteus Fr.

Tremellaceae

Tremella albida Hud.
Tremella fimbriata Pers.
Tremella fuciformis Berk.

Thelophoraceae

Coniophora cerebella Pers.
Stereum hirsutum Fr.
Thelephora multipartita Schw.

Lycoperdaceae

Bovistella Ohiensis E&M

Sclerodermataceae

Scleroderma lycoperdoides Schw.

Ascomycetes

Durandiomyces Phillipsii Seaver
Elvella elastica Bull
Hypomyces lactifluorum Schw.
Morchella angusticeps Pk.
Paxina semitosta B & C
Paxina sulcata Pers.
Peziza domiciliana Cook
Peziza venosa Pers.
Plectania floccosa Schw.
Plectania occidentalis Schw.

Tree Growth Records for Indiana's First State Forest

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Indiana's first State Forest had its beginning in 1903 when the Indiana State Board of Forestry purchased 2000 acres of land in Clark County. It consisted of approximately 20 old farms. The early objectives for the forest reservation were to cultivate the timber and to plant seeds and seedlings in the cleared portions. Since the wooded area had been cut over and burned prior to its acquisition by the State, it was recognized that protection from fire and livestock grazing were needed. The old fields were considered suitable for experimental tree planting and so this phase of forestry work occupied an important place.

Tree planting began in the fall of 1903 when some of the old fields were directly seeded with various species of hardwoods. The hardwoods used were black walnut, oaks and hickories. The results secured from these seedings were not too encouraging because the rodents destroyed most of the seed. The records show that each fall and spring during the years of 1903 to 1908 direct seeding and planting of hardwoods was done on the old fields. However, the records of these first few years were not very specific and hence little can be gained from them.

In 1909 Charles C. Deam was appointed State Forester and soon after that he organized the reforestation experiments. He kept detailed records of the experimental plantings and for nearly 20 years he directed the tree planting experiments.

Deam's (1) summary in 1910 showed that between the years of 1903 and 1910, 28 old fields consisting of about 110 acres were seeded or planted. Nineteen different hardwoods were used in these experiments.

In order to encourage the growth of the seeds and seedlings the old fields were plowed and disced prior to tree planting or seeding. Each season most of the plantations were cultivated. Cultivation meant a plowing and when the trees were young it was thought necessary to plow between the rows three times during each season. When the trees were four or five years old it was thought necessary to plow very shallow once or twice between the rows during each season. Hoeing was also done and it meant cutting down the weeds, grass, shoots, sprouts and briers left by the plow. Growing corn crops between the tree rows was also a practice. As the trees developed, cultural measures included pruning, thinning and coppicing. Replanting of the failed places was also done for one or more years following the initial seeding or planting.

Some of these early reforestation experiments were initially successful. The initial establishment and growth of black walnut *(Juglans nigra)*, tulip poplar *(Liriodendron tulipifera)*, black locust *(Robinia pseudo-acacia)*, chestnut *(Castenea dentata)*, and catalpa *(Catalpa bignonioides)* were satisfactory. The results with other hardwoods like

elm *(Ulmus sp.)*, Kentucky coffee tree *(Gymnocladus dioica)*, the oaks *(Quercus sp.)*, and the hickories *(Carya sp.)*, were not encouraging. One of the species which showed considerable promise was white ash. The 1910 report stated that white ash *(Fraxinus americana)* was one of the most desirable forest trees to plant in Indiana. This conclusion was based on the results secured on nine acres of ash plantings that were either directly seeded or planted.

Hardwoods continued to be used for tree planting and some species like sycamore *(Platanus occidentalis)*, tulip poplar *(Liriodendron tulipifera)*, ash and black cherry *(Prunus serotina)* continued to show fair development. As the yearly records of the direct seeded and planted areas began to accumulate it became apparent that the growth and development of hardwoods were very unsatisfactory.

In 1923 Deam (2) published a summary of the reforestation experiments for 80 different experimental tracts. By this time many of the hardwood direct seedings and plantings had failed to develop into good young stands. Many of these hardwood experimental areas were underplanted to white pine.

The failure of the hardwoods, the good initial survival and early growth of a few of the older coniferous plantings, and the availability of coniferous planting stock all contributed to the general use of conifers.

To show what has taken place on the old fields which were direct seeded or planted to hardwoods, case histories of areas representative of the reforestation experiments are presented. These selected tracts also represent the longest period of time and they illustrate the forest successional trends on the old fields.

White ash was planted on several areas and Tract I illustrates one of the oldest plantings. White ash seed was drilled thickly in rows in the fall of 1904. Good germination and survival resulted and in the fall of 1906 it was thinned leaving the stand with trees on approximately a 4x4 foot spacing. The trees were cultivated for several years and in 1910 the trees were pruned. In 1915 measurements of the ash were as follows:

Trees Unpruned	1.2 inches d.b.h.
Trees Moderately Pruned	1.1 inches d.b.h.
Trees Severely Pruned	1.4 inches d.b.h.

Apparently these results lent little encouragement to future management since the plantation was left to develop without further cultural treatment. In 1950 nearly half of the original stand is still present. Growth of the ash has been very poor because the 46 year old trees are only 3 to 6 inches d.b.h., with a few trees attaining a diameter of 8 inches. Failure of the ash to attain larger size is probably due to the poor site and because it does not naturally occur or grow in pure stands.

Tract 61 is a sycamore plantation consisting of approximately 4 acres. Seedlings were planted in April 1913 and good establishment resulted. The trees were spaced 4x4 and 5x5 feet, part of them being cultivated for two years and the others receiving no cultivation. For

a few years the trees which were cultivated grew better than the uncultivated trees. This was a temporary condition and as the plantation continued to develop without cultivation, differences in the two plots were not noticeable. After 37 years, half of the planted trees are still present and the trees are now from 3 to 6 inches in diameter. Many of the trees are partly dead and will probably die out during the next few years. Natural succession of sweet gum, tulip poplar, ash, and Virginia pine has taken place and some of these trees are larger than the planted sycamore. Natural seeding of Japanese red pine from planted trees is also found on a portion of the area. Failure of the sycamore to show better development is not due to site but because pure stands of sycamore are unnatural.

An experiment to determine the relative rate of growth and shade tolerance of several hardwoods is found on Tract 74. In May 1913 seedlings of ash, chestnut oak *(Quercus prinus)*, basswood *(Tilia americana)*, black locust, catalpa, elm, sycamore and tulip poplar were planted. The plan was to grow one row of each species between two rows of each of the other species. In 1914 replanting was done in order to have a complete stand. The area was plowed and disced prior to planting and the trees were cultivated for two years. The chestnut oak failed to grow and the survival of the other species ranged from 65 to 90 per cent. Height growth for a few years after establishment varied from the black locust which grew most rapidly to basswood which made the poorest height growth.

In 1923 sugar maple seedlings were underplanted in the center of the space between each four trees. The initial survival of the maple was about 90 per cent.

The plantation was first thinned in 1937 when a few black locust, which had grown to post size, and some poorly formed tulip poplar and sugar maple were cut. No other treatment has been attempted and the stand in 1950 is composed largely of sugar maple. Seventy-five percent of the 27 year old sugar maple are still present and they vary from 2 to 7 inches in diameter. About 10 per cent of the tulip poplar are present and they are from 5 to 17 inches d.b.h. The other species that were planted are represented by only a few scattered trees none of which have attained a diameter exceeding 5 inches.

The stand is still very dense and forest floor conditions are typical of a closed hardwood stand, with a good cover of hardwood leaves and litter. A few sassafras, black cherry and Virginia pine have come into small openings. Although the growth and development of sugar maple when underplanted or interplanted with other hardwoods is not satisfactory, the experiment does illustrate its extreme tolerance as well as its persistency.

The growth and development of the tulip poplar in this mixed stand is very similar to that exhibited when it grows naturally in the hardwood forest. It tends to be very intolerant and consequently only a few trees survive the competition and tulip poplar occurs as an occasional tree or group of trees in mixture with other hardwoods.

The three cases illustrate what has been the trend when hardwoods were used to reforest old fields. They show that, given enough time to develop, some of the planted hardwoods will grow to merchantable size and eventually form part of the mixed hardwood forest. It is also evident that hardwoods do not grow well in pure stands when planted or seeded on an old field. Apparently hardwoods grow best in mixed stands, in competition with other species and on forest soils. *Old field soil and site conditions appear to be unfavorable for the hardwoods.*

An example of the early hardwood planting which was later planted to white pine is indicative of similar results which were encountered on many of the old fields. Tract 37 was direct seeded to hickory in 1904-1905. A fairly good stand resulted but by 1908 it was thought advisable to plant seedlings of elm and ash. The trees were cultivated for four years and the ash was given a moderate pruning in 1911. In 1919 the average d.b.h. of the ash was 1 inch and the elm 0.7 inches d.b.h. In May 1920 the vacancies in the ash were replanted with white ash seedlings. The elm were practically all dead in 1920 so in 1921 white pine was planted where the elm had failed.

In 1950 the 30 year old white pine is from 3 to 13 inches in d.b.h. and there are approximately 250 stems per acre. The 45 year old hickory still persists but most of the trees are less than 6 inches d.b.h. There are a few elm and ash trees, 1 to 3 inches d.b.h., growing on the area.

Although the white pine have shown good establishment and growth it was necessary to cut out the competing sassafras, persimmon, Virginia pine, and other species as well as cutting vines in order to favor the white pine. Thinning and pruning of the white pine have also been done and to grow the white pine to larger size cultural practices will need to be continued.

Conclusions

Old fields are not suitable for planting or direct seeding hardwoods.

Old field soils have neither the organic content, water holding capacity nor porosity necessary for the growth of hardwoods.

A pine crop can be grown on an old field with proper care and management and at the same time encourage natural hardwood succession.

More time is required to judge the results of a hardwood planting than that of a coniferous planting.

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The Phytopathology of *Mentha piperita* L.

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Peppermint oil is one of the most valuable of the volatile oils and one of the few such oils produced commercially in the United States. This oil is used extensive'y in pharmaceutical preparations, dentifrices, confections and chewing gum. There is also a limited quantity of peppermint oil exported.

The cultivation and production of peppermint, *Mentha piperita* L., and peppermint oil has reached a very advanced stage in specialization of methods and equipment used in its production on a commercial scale.

References to peppermint oil can be found in such early writings as those of Synesius of Alexandria in 410 A.D. However, the peppermint plant of the present day, *Mentha piperita*, was first mentioned by John Ray, in England in 1696 (5). The exact origin of commercially-grown peppermint is obscure, but most botanists agree that it arose as the result of natural hybridizations that occurred many years ago (1).

Peppermint plant stock was imported to this country from England in about 1812. The first plantings were made at Ashfield, Massachusetts. From this early beginning, the crop was established in Wayne County, New York, and this area soon became the leading producer of peppermint oil in this early era.

Gradually, the industry migrated westward to Ohio and then to southern Michigan. The muck and peat soils of St. Joseph County were so well adapted for the cultivation of mint that total acreages increased many fold in a short period. Since northern Indiana has extensive areas of the same muck type of soil, peppermint was introduced into this state and many growers soon were cultivating this plant as a major crop. At the present time, the centers of mint production are found near the cities of South Bend, North Judson, Rensselaer, Bremen, Nappanee, and Columbia City, Indiana (5).

The midwestern mint-producing areas held a virtual monopoly in the production of peppermint oil until comparatively recently. In the past few years the Pacific coast states of Washington, Oregon, and California have expanded mint plantings which were made in these areas as early as 1919.

TABLE I. Peppermint Acreages and Yields

State	1938-48 Ave	1950	Yield/Acre 1939-48 Ave. lb./Acre	Yield/Acre 1950
Indiana	14,920	16,500	29.0	26.0
Michigan	14,780	10,000	23.2	33.0
Ohio	110	.	34.0	....
California	570	. .	35.9	. . .
Oregon	6,240	14,400	43.4	49.0
Washington	3,190	5,100	46.4	60.0
Total	39,810	46,000	30.4	35.4

As Table I indicates, the total acreage devoted to peppermint production in Indiana is 16,500 acres, with an average yield of 26 lb./acre. This is approximately 600 acres more than the 10 year average of 14,920 acres for 1939-48, but the average yield is two pounds less per acre. The price of peppermint oil at the present time is between $3.50 to $5.00 per pound, so the gross income to Indiana growers is some $1,700,000 annually.

The acreage devoted to the cultivation of peppermint in Michigan this year shows a decrease of 4,780 acres over the ten year average. However, the average yield per acre is some ten pounds higher for 1950 than the average yield for 1939-1948. This may be explained by the fact that the production of peppermint is now in the hands of a relatively few growers in that state. These producers have extensive plantings and operate much more efficiently than the small producers are able to operate. These small growers are being forced to abandon this crop for reasons which shall be brought forth later.

This table also indicates the rapid ascendancy of the western states in mint oil production. Special note should be made of the high yields per acre which are realized, especially in the states of Washington and Oregon. These differences in yield may be partially explained by noting the different methods of cultivation employed in the two areas. Practically all of the mint grown in the western states is planted in small acreages and in rows. This is to facilitate irrigation, which is necessary in these areas. Such practices also enhance cultivation and weeding.

In the midwestern region, mint is only grown in rows for the first year and cultivated. The following year it is allowed to spread into meadows. Some overhead irrigation is practiced but, for the most part, controlled water tables are relied upon to furnish adequate moisture for growth.

Although these cultural practices certainly have some bearing upon yields, the major cause for this difference is the incidence of disease.

The three principal diseases of *Mentha piperita* L. in the Indiana-Michigan area are *Verticillium*-wilt, anthracnose, and mint rust.

Verticillium-wilt is the most serious disease of mint in southern Michigan and northern Indiana at the present time. The total acreage devoted to mint production has decreased rapidly in Michigan since 1939 and the full effect of this disease is now being felt in Indiana.

This disease is caused by one of the Fungi Imperfecti *Verticillium albo-atrum*, R. & B. It was first reported by Nelson (6) near Kalamazoo, Michigan, in 1926. The disease spread rapidly throughout the state and was reported in Indiana for the first time by Baines in 1941 (2).

To illustrate the severity of this disease, Ellis and Stevenson (4) noted that the total acreage devoted to mint decreased in Clinton County, Michigan, from 19,000 acres in 1935 to only 2,300 acres in 1946. They attribute this decline wholly to the incidence of *Verticillium*-wilt.

Plants infected with this disease show marked stunting and lack of vigor. The apical leaf whorls map show bronzing and asymmetrical

development of some of the leaves. The symptoms encountered later in the growing season are general chlorosis of the leaves of infected plants and progressive necrosis from the base of the stem upward. This is due to a hadromycosis of the vascular tissues, particularly the xylem.

Young plantings may be killed by this attack and older fields are markedly reduced in stand and vigor. Once infected, plants never recover from this disease. In addition to the direct effect of the disease, infected plants are much more susceptible to winter kill than are normal plants.

Although the life cycle of the casual organism is not fully understood, it is fairly well established that infection takes place through the roots and stolons in the soil. Symptoms of the disease may be suppressed until the advent of hot weather when the plugged vascular tissues fail to compensate for moisture lost during the day. Infected plants seldom "wilt" in the true sense of the term, however; so the common name of this disease is not particularly appropriate.

Since this is evidently a soil borne disease, the problem of control is quite complex. There are few means of combatting pathogens of this type directly. Crop rotation programs have been instigated and it was shown that a three-year rotation program is not of sufficient length to reduce the population of the causal agent in the soil so that mint can be grown successfully on infested soils. Longer rotation trials are now in progress.

Attempts have also been made to breed resistant varieties of *Mentha piperita* L. This program has been hampered by the fact that this species of Mentha produces male sterile flowers. Resistant crosses have been developed, using pollen from some other species of the genus *Mentha,* but the quality of the oil produced is not acceptable.

Certain cultural measures, such as controlled water tables in the drained muck soils and overhead irrigation, have permitted profitable yields but offer no permanent promise of control.

If the chain of events in Michigan can be used to predict the future of the mint industry in Indiana, the outlook is not favorable. Acreages will decrease as the small, marginal growers are forced to other crops because they can no longer raise mint profitably. The larger, more efficient operators, through improved cultural methods, will still be able to grow mint on a profitable scale but eventually the soils will become so infested with the casual agent of Verticillium wilt that the crop will be abandoned. It is not pessimistic to say that the future of the peppermint oil industry in the midwestern region depends upon a feasible control of the disease *Verticillium*-wilt.

Verticillium-wilt is not known to be present in the mint plantings found on the west coast at the present time.

The anthracnose disease of mint ranks second in importance in this area. This disease has been destructive at times in Indiana but is not often of epiphytotic proportions.

The symptoms of this disease on the leaves are small, brown, depressed lesions which gradually enlarge and become oval in shape. The centers of these lesions become ash-grey in color and may coälesce.

Necrotic areas may develop in the leaf tissues and drop out, causing a typical "shot hole" effect.

The stem lesions enlarge rapidly and cause extensive cankers in the cortical tissues. These lesions are usually brown to reddish-brown in color.

The causal organism of mint anthracnose was first described by Baines in 1933 (3) and later identified as *Sphaceloma menthae* by Jenkins (6) in 1937.

The casual agent produces condiospores abundantly in the leaf and stem lesions and these spores are disseminated by wind and splashing rain. The fungus overwinters on old mint refuse in the field but evidently not in the soil proper.

The most effective means of control has been to carefully plow under all mint in the fall. Trash shields are recommended to insure that all the plant debris is covered (8). If all plants are buried adequately new growth in the spring is seldom affected even though the previous crop may have shown a high incidence of this disease. Since this cultural practice is also recommended to protect overwintering plants against cold injury, it is followed extensively in the Indiana mint growing regions.

Such measures as frequent dusting with 20-80 copper-lime dust or spraying with 6-6-100 Bordeaux mixture are also effective and may be utilized in localized outbreaks of this disease.

Puccinia menthae, Persoon, the causal agent of the rust found on *Mentha piperita*, L. is autoecious, with all the spore stages occurring on this host. It is not a serious disease under Indiana conditions but is severe on the West coast.

The first symptoms appear in the spring or early summer. These are yellow to brown, eruptant lesions which are accompanied by considerable hypertrophy of the host tissue. Later in the season, the uredial sori develop and these are followed by the telial or over-wintering spore stage. At this time the lesions are dark brown in color and heavily infected leaves may curl and die. This loss of foliage reduces the oil yield since the oil glands are concentrated mainly on the leaves.

Mint rust is evidently held in check in the midwestern region by the practice of late fall plowing previously mentioned. In the western states, where this not done, mint rust is a serious problem.

Other control measures include the application of dusting sulphur at intervals of seven to ten days or spraying with 8-8-100 Bordeaux mixture at similar times.

Summary and Conclusions

As has been indicated, Indiana holds a prominent place in the production of peppermint oil in the United States. The quality of the oil produced in this state is such that buyers prefer it above oils distilled in other areas. There is grave concern, however, over the future of this industry in Indiana and many institutions are devoting considerable

effort to the problems of disease control, plant breeding, methods of harvesting and processing, etc.

In this paper we have been concerned primarily with the prominent disease of peppermint and a brief discussion of the origin and distribution of the crop. *Verticillium*-wilt is the most serious disease in the midwestern region and may well be the cause of the failure of this industry, commercially. In southern Michigan, where this disease is even more serious, much of the land formerly devoted to mint production is being abandoned and growers are seeking new disease-free soil.

Both anthracnose and mint rust are of secondary importance in this area but may cause serious losses locally at certain times. Both of these diseases can be controlled efficiently.

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Differential Responses of Wheat Varieties to Temperature During Vegetative and Reproductive Stages.[1]

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Many aspects of the problem of the adaptation of crop varieties to limited geographical ranges are unsolved, even though numerous studies have been made on the ecology of crop plants. Some progress has been made in the understanding of this phenomenon by the work done on the responses of plants to vernalization, photoperiod, and thermoperiod. An example of a problem which cannot be completely resolved in the light of the previous experimental work as summarized by Murneek and Whyte (2) is found in the performance of certain winter wheat varieties in Indiana. During the past several years, a number of new selections of early winter wheats have markedly and consistently out-yielded standard season varieties in Southern Indiana. These same selections have not shown the same advantage in comparable field trials in Northern Indiana. Data comparing the yields of one of these early selections (4117A16-5-1), an intermediate variety (C.I. 12557), and a medium season variety (Vigo) in replicated rod-row yield trials near Vincennes in Southern Indiana and Lafayette in Northern Indiana for the years 1948-1950 inclusive are presented in Table I.

TABLE I. Average yield in bushels per acre of three lines of winter wheat at Vincennes and Lafayette, 1948-1950 inclusive.[2]

Variety	Season of Maturity	Average Yield Vincennes	Average Yield Lafayette
4117A16-5-1	Early	49.7	38.5
C.I. 12557	Medium Early	42.3	39.2
Vigo	Medium	37.6	39.3

No single factor can be expected to explain the differences in performance of these varieties at the two locations. Limited studies at the Purdue Agricultural Experiment Station have indicated that photoperiod is not a major factor in the adaptation of wheat varieties. Chinoy (1), in India, reported that the yield of wheat varieties may decrease as the temperature during the maturation period increases. The present paper discusses preliminary studies on the relative requirements of the three varieties listed above for vernalization, and on the effect of temperature on the length of time required for vernalized plants to reach flowering and maturity.

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[1] Contribution by Department of Botany and Plant Pathology, Purdue Agricultural Experiment Station Journal Paper No. 510.

[2] Data of Caldwell et al, Ann. Rpts. Purdue Univ. Agr. Expt. Sta. 1948-1950.

Experimental

The three varieties A16 (4117A16-5-1), 12557 (C.I. 12557), and Vigo were space planted in field plots near Lafayette on October 13, 1949. Plants were collected periodically during the following winter and spring and were transferred to pots in a greenhouse maintained near 65° F. Data on the subsequent development of the plants were obtained to determine the relative rapidity of vernalization of the three varieties and the relative rates of growth following vernalization. A portion of the data obtained, based on a sample of twelve plants of each variety, is tabulated in Table II.

TABLE II. Development of wheat plants transferred to the greenhouse from the field at different dates

Date Transferred	Variety	Days following transfer from field	
		to "shooting"	to maturity
11-10-49	A16	124	179
	12557	108	179
	Vigo	120	179
12-3-49	A16	76	135
	12557	80	135
	Vigo	84	135
12-27-49	A16	58	110
	12557	57	114
	Vigo	59	114
2-3-50	A16	27	87
	12557	30	87
	Vigo	30	96
3-4-50	A16	9	78
	12557	10	86
	Vigo	10	90
4-14-50	A16	7	63
	12557	7	73
	Vigo	7	73

Prior to complete vernalization the three varieties required the same length of time to mature under greenhouse conditions. With more nearly complete vernalization in the field, the early A16 matured more rapidly than the other two. This seems to be associated with the speed of development following "shooting" rather than with the length of the period prior to this stage in four of the six collections. For example in the first collection the plants of A16 matured in 55 days following "shooting" whereas 12557 and Vigo required 71 and 59 days respectively. The data in Table II are interpreted as indicating

that vernalization is gradual and accumulative rather than being suddenly effected following a given minimum period of exposure to low temperatures.

In another experiment the three varieties were transferred from the field to the greenhouse on January 12, 1950. Thirty plants of each of the three varieties were grown under each of the following experimental conditions:

A. Grown to maturity at 65° F.
B. Grown to maturity at 80° F.
C. Grown to flowering at 65° F. and allowed to mature at 80° F.
D. Grown to flowering at 80° F. and allowed to mature at 65° F.

The effects of these conditions on the dates of flowering and maturity are summarized by the data in Table III. The data in Table IV present the effect of the same variables on mature plant and head size.

TABLE III. The differential response of wheat varieties to temperature at different growth stages

Temperature (°F)		Days from potting to flowering*			Days from flowering to maturity**			Days from potting to maturity**		
Before Flowering	After Flowering	A16	12557	Vigo	A16	12557	Vigo	A16	12557	Vigo
65	65	34	39	43	35	37	32	69	76	75
80	80	27	41	57	32	28	27	59	69	84
65	80	34	39	43	30	40	28	64	79	71
80	65	27	41	57	42	40	28	69	81	85

* Average of 60 plants.
** Average of 30 plants.

TABLE IV. The effect of temperature at different growth stages on mature plant and head sizes. (Averages of 30 plants)

Temperature (°F)		Height of Mature Plant (inches)			Dry weight of Mature Heads (grams)		
Before Flowering	After Flowering	A16	12557	Vigo	A16	12557	Vigo
65	65	38.7	41.9	43.6	0.97	1.08	0.98
80	80	23.7	29.1	29.5	0.41	0.63	0.53
65	80	36.0	42.6	43.2	0.79	0.91	0.88
80	65	28.5	32.3	29.5	0.69	0.67	0.65

Under both cool and warm conditions plants of A16 flowered earlier and matured earlier than those of the other two varieties, with 12557 being intermediate, and Vigo being late. The varieties showed striking differences in their responses to the contrasting temperature levels

before and after flowering. For example, A16 flowered one week earlier at 80° F. than at 65° F. whereas Vigo flowered two weeks earlier under the cool conditions. Temperature seemed to have no effect on the length of the period from potting to flowering of 12557. Maturation of A16 and Vigo following flowering proceeded more rapidly under warm than cool conditions. The temperature under which plants were grown to flowering influenced the rate of maturation. For example plants of A16 grown to flowering at 65° F. and maintained at that temperature matured one week earlier than plants grown to flowering at 80° F. and then transferred to the cooler temperature. In most situations the latest variety, Vigo, matured the most rapidly following flowering. It was pointed out in the discussion of Table II, that A16 required less time to mature following the onset of the "shooting" stage than did Vigo. This implies that the period between the onset of "shooting" and flowering is much shorter for A16 than for Vigo. An analysis of the detailed data supports this conclusion.

The temperature sequence under which the plants were grown had a marked influence on the final plant size and yield. All varieties produced larger plants when grown at the cool temperature prior to flowering. The greatest dry weight of the heads resulted when the plants were continued to maturity at cool temperatures. With a minor exception in 12557, a direct relation appeared between the plant height and dry weight of the heads.

Discussion

No problem in adaptation can be expected to be resolved by a study of any single factor. These preliminary studies indicate the importance of the effect of temperature on performance at the different stages of growth of wheat and further disclose a marked interaction between this factor and earliness of maturity. Variety tests at Vincennes, Indiana have shown yield of these three varieties to be inversely related to the length of their growing period. In view of the findings of Chinoy it may be that the high yields of A16 in southern Indiana result from its ability to mature early and consequently at lower temperatures than do later varieties. The failure of A16 to show superior performance at Lafayette is not clear but presumably results from the retarded onset of the "shooting" stage due to the lower spring temperatures. Although A16 is earlier than Vigo and 12557 at Lafayette, Indiana, it is not so much earlier there as it is when grown farther south at Vincennes. This may in part explain its failure to show a yield advantage at Lafayette.

Summary

1. Three varieties of winter wheat varying in their earliness of maturity and adaptation to northern and southern Indiana were utilized in preliminary field and greenhouse experiments to determine the importance of the temperature factor in their development.

2. Vernalization appeared to be a gradual process that required

no critical minimum low-temperature period. With inadequate periods of field vernalization, both early and late varieties required the same length of time to mature under greenhouse conditions. As the degree of vernalization increased varietal differences in time required for maturation became more pronounced.

3. Field vernalized plants of the medium variety (Vigo) flowered much sooner under cool than under warm conditions, while the early variety (4117A16-5-1) showed the reverse response. The intermediate variety (C. I. 12557) was not greatly influenced by temperature in respect to flowering. Two of the three varieties tested matured more rapidly at warm temperatures than cool, although the temperature prior to flowering had an influence on the rate of maturation.

4. Vegetative growth of all varieties was favored by cool temperatures and the average dry weight of the heads produced was directly related to plant height.

5. It is suggested that the superior performance of certain early lines of winter wheat in southern Indiana may be accounted for by their response to the milder temperatures prevailing during their late winter and spring growth.

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The Effect of 2, 4-D on Well Established Grape Vines

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Three young grape plants of the Concord variety were planted in the Spring of 1930, on the property line between my own yard and that of the lot north of mine. Two of the plants were located in open space between the two properties. The third plant was in line with the other two but was south of a garage. All three plants bore fruit and leaves normal for the variety from the date of planting until the summer of 1949.

The three plants were pruned heavily in March, 1949. That same year at the time when the vines were in blossom, 2, 4-D was used as a weed spray in the lawn north of the vines. No spray was applied directly to the vines but a north wind carried a mist of spray across the exposed vines. Apparently the vine south of the garage was so well protected that little, if any, of the spray drift came in contact with it.

The fruit borne on the exposed vines in the autumn of 1949 were colored normally but the fruit bunches and the individual berries remained small. The leaves likewise were modified in appearance and size.

Fruit and leaves borne on the protected plant were normal in appearance and quality.

The vines were not pruned in the spring of 1950. Again, this year, the fruit and leaves of the exposed vines exhibited the same abnormal tendencies as were noted the previous year. Also, in 1950, the protected plant again produced normal and characteristic fruit and leaves.

The leaves of the plants that had suffered 2, 4-D injury differed from normal leaves in that the area had been reduced one half. The affected leaves were more uniformly and deeply serrate without the tendency to lobing characteristic of the leaves of the Concord variety. The affected leaves were a much darker green than were the leaves of the protected plant.

The fruit bunches from exposed plants had a ratio of length to normal leaves of 2 to 3. Bunches had a tendency to branch. The berries on each bunch were much smaller than normal and were more closely crowded. The berries had well formed seeds.

In 1840 boys who had gathered wild grapes along the river at Concord, Massachusetts, ate them in the yard of Ephriam W. Bull and threw the seeds away. The next year Bull noticed that some of these seeds had sprouted and he protected the little plants until the first bunch of grapes appeared in 1843. Seeds from this bunch were planted and fruited in 1849. The fruits were so excellent that Bull exhibited them at a meeting of the Massachusetts Horticultural Society in 1853. In this fashion the variety known as the Concord grape came into being.

Hedrick in his Grapes of New York thinks that this grape is a mutation of *Vitis labrusca,* the fox or skunk grape. Others believe because of stamen differences that it may be a cross between *V. labrusca* and some other species. Bull himself mentions that a Catawba grape was growing near by and his wild seedlings may have picked up some of this pollen. Today the Concord variety represents 75% of all the grapes grown in the Eastern United States. Furthermore, the Concord is the parent of many other of our domestic varieties.

Vitis labrusca is a species native to the Atlantic seaboard. It is described by Bailey as a strong vine climbing high on thickets and trees. Leaves, large and thick, strongly veined, broadly cordate-ovate, mostly obscurely three-lobed, or sometimes nearly continuous in outline deltoid-ovate, the margin shallowly scallop-toothed with blunt pointed teeth. The upper surface of the leaf is dull green becoming glabrous; but the lower surface densely covered with a tawny white, dun-colored, or red-brown tomentum.

Racemes short, berries usually less than twenty in the wild types, generally simple or very nearly so; berries large and nearly spherical ranging from purple-black to red-brown and amber-green.

I have presented here a series of observations. No claim is made that this record is one of exact experimentation. The amount and strength of the spray drift coming in contact with the plants are not known. It can not be asserted definitely that no spray came in contact with the plant protected by the garage, although it is obvious that it was physically impossible for this plant to receive the dosage to which the exposed plants were subjected.

In spite of these experimental uncertainties, it is evident that two plants exposed to 2, 4-D drift received a dosage that was beyond threshold strength, but less than lethal in amount. The affected plants were considerably modified as to the nature of subsequent fruit and leaf characters. This effect has been maintained for at least one year.

It is also clear that an adjacent plant which received a less amount of the 2, 4-D spray was not affected.

It is idle to speculate as what physiological effect this herbicide has had on the grape plant. It was surmised at first that the spray had caused a reversion to the wild type, but there is nothing in the description of *Vitis labrusca* that would substantiate such a hypothesis. The ease with which the Concord grape has been modified and caused to produce new varieties suggests that 2, 4-D may have been responsible for the creation of a mutation.

Composition of the Forest Primeval from Hendricks County Southward to Lawrence County, Indiana[1]

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The basis of this forest study are the field notes of the surveyors who made the original United States land survey between 1800 and about 1835. These men recorded two "witness trees" at each section and quarter section corners. The common name and the trunk diameter of these trees were given. This procedure placed on record from 2,500 to 4,000 trees for a county. In discussing the importance of the various species or genera in the forest composition, percentage of the total number of stems recorded are used (Tables I, II, III, IV). Usually 34 to 40 species and genera are listed for a given county.

In spite of the numerous field studies made on the phytosociology of Indiana forests, and on climax forest characteristics for the state as a whole, the old Zon (5) map, which places Indiana into the oak-hickory climax, creeps into modern botany texts. Other writers do not go to this extreme but they place the unglaciated section of the state into the oak-hickory climax. Because of such misunderstandings about the Indiana forests the present study has been made to include an area which is representative of both the level glaciated and rugged unglaciated sections of Indiana.

The most prominent single feature of the study is the almost universal important place occupied by *Fagus grandifolia* (beech); in some townships this species represented 60 per cent of the total stems recorded. In the more mesic areas, such as Hendricks County, the chief associates are *Acer saccharum* (sugar maple) and species of *Fraxinus* (ash); however, usually also present in lower percentages were *Nyssa sylvatica* (black gum), *Juglans nigra* (black walnut), *J. cinerea* (white walnut), *Liriodendron tulipifera* (tulip poplar), *Ulmus* spp. (elms), *Cornus florida* (flowering dogwood), *Cercis canadensis* (redbud), *Carpinus* (water beech), *Tilia* (linden, lynn), *Morus* (mulberry), *Prunus serotina* (black cherry) and occasionally *Sassafras*. In the rugged areas *Castanea* (chestnut) appeared. Of course, universally associated in varying degrees were species of *Carya* (hickory) and *Quercus* (oak). Tables I to IV also show that tabulations of individual townships accentuate much more the characteristic of segregation of species into forest cover types than is shown by groupings of whole ranges of

[1] This is contribution 237 of the botanical laboratory of Butler University. The first-named author was aided in this study by a Butler University Faculty Fellowship. Sincere thanks is expressed for this aid. We also express our thanks to Mr. Stanley M. Shartle, Deputy Surveyor of Hendricks County, and officials of the State Auditor's office for co-operation given us in the work.

TABLE I. Representation of stems in terms of percentage which a species or groups of species had of the total number of stems recorded for Hendricks County, Indiana

Species	T. 14 N.				T. 15 N.				T. 16 N.				T. 17 N.			
	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.
Acer saccharum	18.0	15.4	10.0	11.9	11.2	13.2	21.2	22.1	21.2	13.3	11.2	14.0	9.8	9.9	3.4	19.0
Fagus grandifolia	42.3	38.0	54.0	43.3	42.0	40.7	37.8	52.3	33.6	48.8	45.6	44.3	24.7	40.5	31.0	39.2
Fraxinus spp.	11.7	9.3	8.5	6.1	9.3	7.3	10.0	4.0	10.6	8.1	11.1	3.8	12.3	12.4	17.0	8.5
Carya spp.	7.2	1.6	1.0	10.3	12.1	8.6	3.5	7.7	9.7	6.5	4.5	11.8	11.1	4.1	8.7	4.0
Quercus alba	4.5	7.7	5.5	6.4	4.6	3.6	7.0	2.3	7.0	5.8	7.6	5.1	16.0	10.3	6.8	6.4
All other Quercus species	0.9	0.6	3.4	3.3	0.9	3.3	1.6	2.3	1.7	1.9	4.5	2.6	1.2	2.5	7.7	3.2
Liriodendron tulipifera	0.9	1.9	0.7	0.3	...	0.4	3.0	2.0	1.7	1.9	1.4	1.9	1.2	2.8	2.4	4.4
Juglans nigra	2.7	3.2	0.7	0.9	1.8	1.6	2.6	0.6	4.4	1.9	1.0	2.2	1.2	0.8	0.5	1.6
Ostrya virginiana	2.7	0.3	1.0	0.9	2.8	1.6	3.0	0.3	1.7	2.0	3.5	1.9	7.4	1.2	2.4	0.4
Ulmus spp.	...	5.7	6.0	5.2	4.6	4.3	3.0	3.7	2.6	4.5	6.6	4.8	7.4	6.3	12.0	7.7
Stems 32 inches or over	3.6	5.7	5.5	3.3	1.8	2.0	3.0	3.0	3.5	2.6	6.3	1.6	4.9	4.5	4.0	8.3
Floodplain species	1.8	7.0	...	3.6	4.7	2.6	1.6	0.3	1.7	1.6	1.0	1.6	2.5	1.2	6.8	3.2

TABLE II. Representation of stems in terms of percentage which a species or groups of species had of the total number of stems recorded for Morgan County, Indiana

Species	T. 13 N.				T. 12 N.				T. 11 N.			
	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.
Acer saccharum	9.5	19.8	9.6	4.4	16.8	14.0	10.2	13.4	16.9	7.4	6.8	9.3
Fagus grandifolia	34.6	38.6	43.5	53.8	43.5	32.2	57.6	62.9	49.6	35.9	26.6	29.6
Fraxinus spp.	7.4	8.9	9.2	8.3	11.2	4.5	1.7	1.6	11.1	5.2	4.7	3.1
Carya spp.	4.2	13.2	10.0	8.9	3.9	4.9	4.7	9.5	4.5	8.3	5.4	4.2
Quercus alba	1.1	5.1	4.1	2.6	1.3	2.4	5.1	3.4	0.4	8.3	5.8	4.6
All other Quercus species	1.3	4.3	2.5	3.8	0.8	1.8	3.0	0.5	1.2	3.9	1.7	1.6
Liriodendron tulipifera	0.7	1.4	2.5	1.3	0.8	.	3.8	1.7	1.2	2.2	1.3	3.1
Juglans nigra	1.4	0.5	0.4	0.6	2.2	2.4	..	1.1	1.2	1.7	1.7	3.1
Ostrya virginiana	1.1	2.8			1.7	2.8	1.2	.	1.6	4.3	6.5	3.1
Ulmus spp.	3.6	2.8	4.1	7.7	6.9	1.4	1.2	1.1	4.1	2.2	4.1	2.3
Stems 32 inches or over	3.6	1.4	2.5	1.9	3.0	1.1	1.2	3.9	3.3	1.7	1.7	4.7
Floodplain species	21.5	3.3	4.6	7.7	2.6	19.6	0.4	1.1	1.2	7.9	21.8	27.3

TABLE III. Representation of stems in terms of percentage which a species or groups of species had of the total number of stems recorded for Monroe County, Indiana

Species	T. 10 N.			T. 9 N.			T. 8 N.			T. 7 N.			
	R. 1 E.	R. 1 W.	R. 2 W.	R. 1 E.	R. 1 W.	R. 2 W.	R. 1 E.	R. 1 W.	R. 2 W.	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.
Acer saccharum	4.7	8.5	10.1	10.9	10.3	32.3	8.0	31.3	15.9	3.7	3.6	22.1	18.6
Fagus grandifolia	37.2	54.6	59.9	35.9	40.9	30.5	43.8	40.3	26.2	7.4	27.0	30.6	39.4
Fraxinus spp.	0.5	4.2	6.0	0.9	3.4	1.7	.	3.4	3.0		0.9	0.8	4.4
Carya spp.	9.0	5.6	4.0	9.0	6.4	7.5	6.4	4.2	11.6	9.2	10.5	10.6	8.9
Quercus alba	9.0	8.1	2.0	10.0	11.2	6.5	13.3	7.2	7.7	31.4	17.4	12.3	4.9
All other Quercus species	6.9	2.5	2.0	16.8	1.3	2.3	5.9	.	2.2	16.7	12.6	2.1	1.6
Liriodendron tulipifera	4.7	0.3	2.0	2.2	2.5	0.4	0.5	0.8	4.7	3.7	3.2	2.1	1.2
Juglans nigra	0.5	...	0.8	0.9	1.2	1.3		0.4	1.7		0.4	1.2	1.2
Ostrya virginiana	4.7	2.4	0.4	0.4	5.6	1.7	2.6	1.7	1.2		2.2	.	1.2
Ulmus spp.	4.2	0.3	2.8	0.9	3.0	3.5	3.2	2.1	3.0	..	5.0	2.9	3.2
Stems 32 inches or over	1.0	2.4	2.0	1.3	0.4	1.3	0.5	2.1	3.4	1.8	0.9	2.5	2.4
Floodplain species	3.1	1.7	4.0	2.7	1.2	0.8	3.2	1.2	3.0	3.7	1.3	2.5	2.4

TABLE IV. Representation of stems in terms of percentage which a species or groups of species had of the total number of stems recorded for Lawrence County, Indiana

Species	T. 6 N.				T. 5 N.				T. 4 N.				T. 3 N.			
	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.	R. 2 E.	R. 1 E.	R. 1 W.	R. 2 W.
Acer saccharum	7.5	13.7	18.6	22.8	17.6	21.1	12.5	17.9	11.1	20.0	6.3	20.1	9.7	2.6	3.8	10.5
Fagus grandifolia	41.8	43.1	43.6	40.3	51.7	52.5	48.9	45.1	39.5	32.3	19.8	44.8	9.7	11.3	9.7	44.3
Fraxinus spp.	1.2	4.8	1.9	2.2	0.6	5.8	2.1	0.4	5.5	5.2	0.3	3.0	12.1	9.5	1.9	.
Carya spp.	4.3	4.8	5.8	8.0	4.7	0.8	3.0	2.7	6.1	3.2	8.7	2.2	9.7	9.5	12.6	1.9
Quercus alba	19.4	12.4	9.8	3.1	2.7	4.4	4.3	9.2	6.1	8.1	21.8	8.0	22.0	27.0	31.0	8.6
All other Quercus species	6.8	3.6		0.9			0.8	1.8	1.3	5.3	7.5	1.5	4.8	6.9	7.4	9.6
Liriodendron tulipifera	1.9	1.3	2.9	4.0		1.3	3.9	3.2	1.8	2.8	6.0	2.2	2.4	11.3	5.7	6.3
Juglans nigra		1.3	1.0	.4	1.4	2.2	0.9	0.5	3.6	0.5	1.1	1.1	.		1.0	1.0
Ostrya virginiana	1.9	3.1	1.9	2.2	4.0	2.2	4.8	3.2	6.7	4.8	1.5	1.1	2.4	.	.	1.9
Ulmus spp.	1.2	2.6	2.9	0.4	4.0	3.1	4.8	1.3	0.6	3.3	2.7	2.2		1.7	2.9	1.0
Stems 32 inches or over	1.2	...	1.5	0.4	0.6	0.4		.	2.5	1.0	0.3	1.1	2.4	0.9		1.0
Floodplain species	1.2	0.4	3.9	1.8	1.4	1.3	1.3	1.8	9.2	2.9	1.5	4.1	7.3		4.8	1.8

townships. Local control, or selection by habitat, is evident even for beech (compare table I with the records in T. 4 N. and T. 3 N. of table IV). In this overall view of a large forested area one sees no evidence of a sharp break between a mixed mesophytic forest cover in glaciated and oak-hickory in unglaciated areas. The data rather point to a mixed mesophytic forest in which the oak and hickory element is more prominent in rugged areas. Most striking of all is the decrease of *Fraxinus* as one proceeds from glaciated to unglaciated sections. Sugar maple and beech fluctuate in a manner that suggests physiographic rather than climatic influence. Potzger and Friesner (2) and Potzger (1, 3) showed such conditions to operate in the rugged sections of Indiana. *Liriodendron tulipifera* and *Juglans nigra* were not very abundant but were represented by massive trees. In the glaciated section of Hendricks County (Table I) *Quercus alba* far outnumbered all other species of oaks. In the glaciated area also trees of 32-inch diameter or over were more numerous than in the rugged unglaciated area, but even here they seldom attained 5 per cent of the total stand. This indicates that the forest primeval was constituted primarily of trees whose diameter of trunk was not strikingly massive. This was the conclusion reached by Potzger and Friesner (4) in their quadrat study of a comparatively little disturbed oak forest. In the tables I to IV floodplain forest designation comprises such species as *Acer negundo* (boxelder), the soft maples, *Platanus occidentalis*, (sycamore), *Celtis occidentalis* (hackberry), *Populus deltoides* (cottonwood), and *Salix* (willow).

Discussion

Descriptions of the phytosociology of forests are not easy to carry out even for a small stand of timber, and the difficulty of such a task mounts as geographical areas widen. In a complex forest cover as we have in Indiana segregation occurs readily with variation in slope exposure and other physiographic changes. This was discussed by Potzger (3) for Ripley County. Slope exposure thus becomes a selective microclimate within an otherwise uniform macroclimate. Potzger and Friesner (2) have pointed this out for the unglaciated areas in the state and discussed in detail the factors which operate. Such local differences may, indeed, be at times of sufficient magnitude to border on macroclimatic significance as Potzger (1) shows for north- and south-facing slopes in Monroe County. If these various local facets are merged in a composite picture, as in the present study, the true climax (climatically controlled) stands out prominently.

It seems to us that the survey data taken uniformly from all types of habitats should present a fairly accurate over-all picture of the *status quo* in a county or series of counties. Since in unglaciated Indiana slope exposure determines the forest cover types, which in its extremes is expressed as oak-hickory on south-facing slopes and mixed mesophytic on more gentle north-facing slopes, it becomes a problem of determining which of the two exposures is most abundant in a given county in

order to know which forest cover is most abundant. We are of the opinion that the records of the surveyors serve this purpose very well. Percentages shown in tables 1-4 justify the conclusion that Morgan, Monroe and Lawrence counties have less area in south-facing slopes than mesic level areas and north-facing slopes, for the over-all picture indicates a mixed mesophytic forest cover with somewhat greater intrusion of the oak-hickory element that in Hendricks County.

Summary

1. Data shown in 4 tables are based on tabulations of trees recorded as witness trees by surveyors of the original United States land survey.

2. Numbers of stems recorded in the several counties included in this study total between 3,000 and 4,000 stems per county

3. Hendricks, Morgan, Monroe and Lawrence counties were included in the study because they are good representative areas of glaciated and unglaciated Indiana. The glacial boundary passes through T. 10 N. in Monroe County.

4. *Fraxinus* decreases in abundance as one proceeds from Hendricks County southward to central Lawrence County.

5. *Juglans nigra*, *Liriodendron tulipifera* as well as stems of large trees (32 inches or over in diameter) seldom attain 5 per cent of the total stems recorded.

6. Percentage representation indicates that the climax forest in all four counties is the mixed mesophytic type. Beech and sugar maple are as a whole the dominant species but oaks and hickories assume a more prominent place in the forest cover of the counties located in the unglaciated area.

7. Listing percentages by townships, as in tables I to IV, accentuates segregation of species into various forest cover types, in which, however, beech and sugar maple usually play a leading role.

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A Systematic Study of the Herbaceous Plants and Shrubs in Christy Woods

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The purpose of this report was to show how an outdoor area, which is owned by a state educational institution, was used by a graduate student for scientific research. The research was to provide helpful biological information for science teachers and students who study in the area. Christy Woods, a part of Ball State Teachers College Campus was the area selected for this study. This is at Muncie, Delaware Çounty, Indiana.

The problem was a taxonomic study involving the identification and the classification of the herbaceous plants and shrubs found growing in a given area in Christy Woods. This work was done to provide a check list of all species found growing in the woods during the period from June 26, 1945 to June 26, 1948. A list such as the one which has been compiled may be used in the identification of the species, and also in making the numerous individuals who visit Christy Woods aware of the fact that there is a vast storehouse of native woods plants at their disposal for observation, study, and enjoyment. Along with the taxonomic study of plants a number of plants were collected, preserved and reported in the publication prepared by the Indiana Academy of Science as new reports for Delaware County, Indiana. The newly reported species were mounted and added to the Ball State Teachers College Herbarium as reference material.

Christy Woods is an outdoor biological laboratory which presents scientific problems. It is a tract of land of approximately eighteen acres and it had been cut over numerous times and was used as a pasture prior to its acquisition by the college in 1918. Since that time the woods has been left to revert back to a natural state and the Oak-Hickory sub-climax is now the dominant vegetation. However, with the pre-dominant number of Beech-Maple seedlings present it was assumed that the woods is entering into the final stage in succession.

An eight acre heavily wooded area, which is typical of the woods found in Central Indiana, was used for the study. The eight acres lies directly west of the campus proper and is divided into twenty-four quadrats each being one hundred square feet in area.

For the survey and the collection of plants to be recorded a schedule was set up whereby a trip was made through Christy Woods each five to seven days during the season of blooming. A specimen of each species of plant was collected and a record was made at the time of the collection. The record included the date of collection, the relative abundance and the distribution of the species in the woods. The plants collected were then brought into the laboratory and identified. A record of the foregoing information, along with the scientific name,

the common name, the family name and range of distribution in Indiana was recorded in a card file. Deam's (1) Flora was used in the naming of the species. In case the author was not satisfied with her identification of the plant the specimen was sent to Dr. Ray Friesner, Professor of Botany, of Butler University, for verification or identification. The check list included the blooming dates of each of the species listed.

Two hundred twenty-six species of shrubs and herbaceous plants (exclusive of the grasses and sedges) were found growing in Christy Woods. These were grouped as follows:

1. Cultivated Shrubs	4
2. Native Shrubs	16
3. Cultivated Herbaceous Plants	3
4. Native Herbaceous Plants	203

The distribution maps in Deam's *Flora of Indiana* were checked and if it was found that any of the plants collected in Christy Woods had not as yet been reported from Delaware County, Indiana, the plant was sent to Dr. Friesner. There a record was made that the plant was a new report for the county. There were eighty-five new records for Delaware County from Christy Woods. Seventy-five of the reports have been published in the Proceedings of the Indiana Academy of Science and accredited to Ball State Teachers College. Each of the eighty-five specimens was mounted and added to the Ball State Teachers College Herbarium.

Additional Taxonomic Work

Additional taxonomic work which was done in conjunction with the foregoing study included eighty-six new reports from various counties and areas other than Christy Woods. They are as follows:

Adams County	6
Grant County	1
Jay County	1
Henry County	9
Wayne County	2
Wells County	2
Delaware County	65
Total	86

The total number of new reports from Ball State Teachers College since 1946 is one hundred seventy-one. The new reports of most interest are the following:

1. *Antennaria neodioica*—reported from nine other counties.
2. *Echium vulgàre*—reported from nine other counties.
3. *Arabis glabra*—reported from eight other counties.
4. *Alyssum alyssoides*—reported from seven other counties.
5. *Hesperis matronalis*—reported from six other counties.
6. *Sedum acre*—reported from three other counties.

7. *Myosotis macrosperma*—(Wells County), the only county in the northern part of the state. Had been reported from four counties in the southern part.
8. *Holosteum umbellatum*—recently reported from Montgomery, Porter, and Delaware counties.
9. *Descurainia sophia*—reported only from Marion and Delaware counties.
10. *Arabis hirsutus* var. *adpressipilis*—reported from Pulaski and Delaware counties.

Studies in Indiana Bryophytes VIII

WINONA H. WELCH, DePauw University

The introductory remarks for this study are comparable to those in the preceding numbers of this series. The descriptions of the species have been omitted because of the high cost of printing. They may be found in books concerning the mosses of North America and Europe.

Research grants from the Indiana Academy of Science through the American Association for the Advancement of Science and from the Graduate Council of DePauw University have aided the author in continuing these studies of Indiana bryophytes. The writer is indebted also to the University of Iowa for an Honorarium which was used in studying the mosses herein discussed under the leadership of H. S. Conard at the Iowa Lakeside Laboratory during the summer of 1950. The author wishes in this way to express deep appreciation of Dr. Conard's counsel.

BRYACEAE

Plants commonly tufted; stems short to 8 cm. in length, erect, usually matted with radicles near base, frequently branching by subfloral innovations; leaves of various shapes, frequently with a differentiated border of narrower cells, costate; inflorescence terminal, dioecious, synoecious, or paroecious; seta elongated; capsule horizontal to mostly pendulous, with neck usually clearly differentiated; peristome double, teeth of outer peristome sixteen.

Key to the Genera of Bryaceae

1. Plants robust, with subterranean rhizome-like growths giving rise to erect shoots with terminal rosettes of leaves . . . *Rhodobryum*
   Plants not as above 2
   2. Leaves very narrowly linear-lanceolate (hair-like), with broad flattened excurrent costa. . . . . . . *Leptobryum*
   2. Leaves broader, with narrower costa 3
      3. Plants whitish green or silvery 4
         4. Plants whitish green, in large soft lax tufts; leaves distant, irregularly spreading . . . . . . *Pohlia*
         4. Plants whitish or silvery, usually densely tufted; leaves close, imbricate . . . . . . *Bryum*
      3. Plants green 4
         4. Leaves ovate or ovate-lanceolate to oval, margin entire or nearly so, often with a border of narrower cells, median cells rhomboidal-hexagonal . . . . . . *Bryum*
         4. Leaves ovate-lanceolate to linear-lanceolate, margin slightly

denticulate toward apex, without a differentiated border, median cells linear to elongate-hexagonal *Pohlia*

Bryum

1. Plants whitish or silvery, leaves without a differentiated border....2
   2. Costa ending below apex in most leaves .... *B. argenteum*
   2. Costa percurrent to shortly excurrent *B. argenteum* var. *lanatum*

1. Plants green, sometimes colored with red and brown, costa percurrent to long excurrent 2
   2. Costa ending below apex to shortly excurrent 3
      3. Plants low, 0.5-1 cm. in height 4
         4. Leaves variously contorted, often twisted when dry, somewhat decurrent; median cells of leaves broadly hexagonal, up to 70 x 35μ . ... *B. capillare*
         4. Leaves not distorted when dry, not decurrent; median cells of leaves irregularly rhomboidal, up to 35 x 15μ *B. bicolor*
      3. Plants often elongated, up to 8 cm. in height, leaves contorted when dry, slightly to long decurrent; costa percurrent to shortly excurrent; median cells of leaves 35-50μ long *B. bimum*

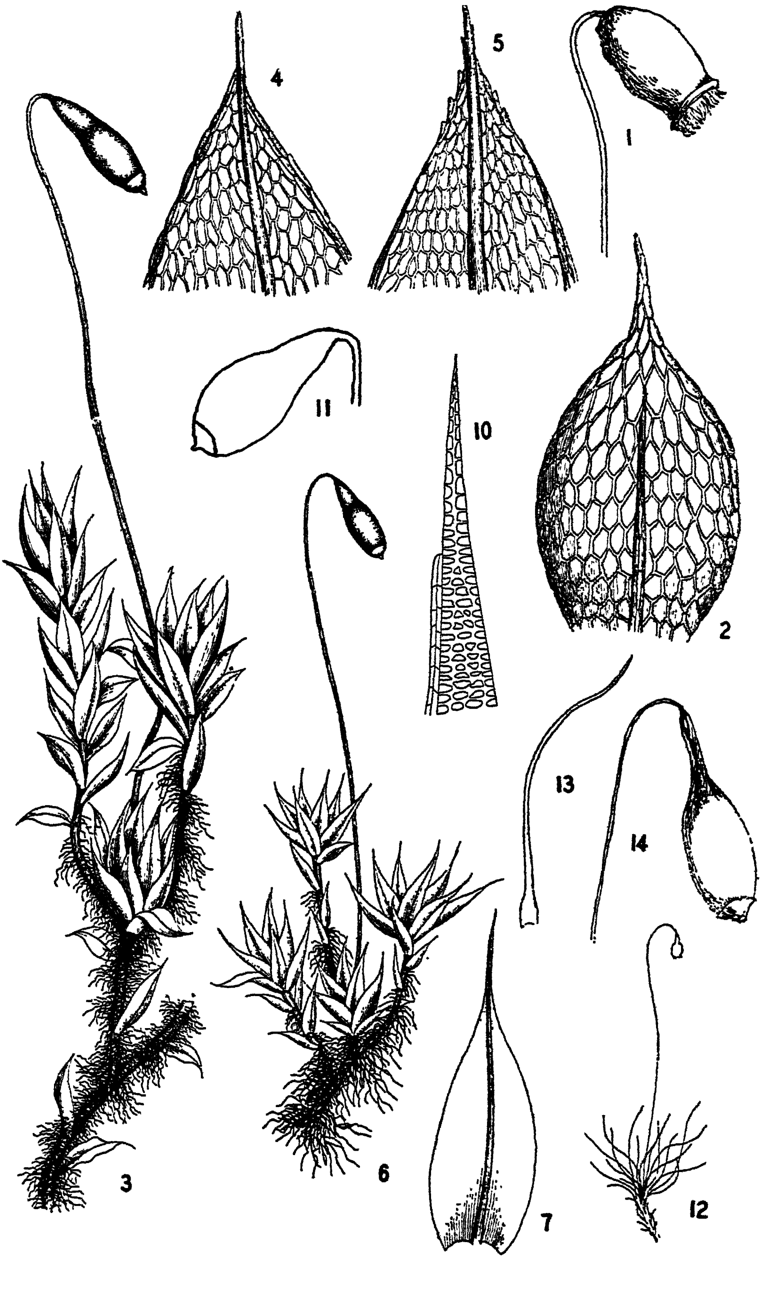
   2. Costa long excurrent, especially in uppermost leaves 3
      3. Leaf tips irregularly contorted when dry; costa very strong or conspicuous; diameter of operculum conspicuously smaller than that of middle portion of urn, lamellae of ventral surface of peristome teeth joined by cross walls . *B. pendulum*
      3. Leaf tips and capsules not as above 4
         4. Leaf margins strongly revolute; median cells of leaves approximately 7:1, up to 70μ in length; inflorescence dioecious ....*B. caespiticium*
         4. Leaf margins not noticeably revolute; median cells of leaves 3-5:1, rarely above 60μ long; inflorescence synoecious ....*B. cuspidatum*

B. argenteum [L.] Hedw. (Figs. 1-2.) Carroll, Cass, Decatur, Delaware, Dubois, Hamilton, Henry, Jasper, Jefferson, Lagrange, Lake, Lawrence, Monroe, Noble, Parke, Perry, Porter, Pulaski, Putnam, St. Joseph, Steuben, Warren, Warrick, and Wayne counties.

B. argenteum var. *lanatum* (P. B.) Br. and Sch.* Carroll and Porter counties.

B. bicolor Dicks.* (Determination checked by A. L. Andrews.) Jasper county.

B. bimum Schreb. (*B. pseudotriquetrum* Schwaegr.) (Figs. 3-5.) Delaware, Hamilton, Henry, Jasper, Jefferson, Jennings, Lake, Madison, Noble, Owen, Perry, Porter, Pulaski, Putnam, Ripley, Wayne,, and Wells counties.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B. caespiticium [L.] Hedw. (Figs. 6-7.) Carroll, Cass, Delaware, Grant, Huntington, Jasper, Jefferson, Lagrange, Lake, Madison, Marion, Marshall, Monroe, Montgomery, Newton, Noble, Owen, Parke, Porter, Posey, Pulaski, Putnam, Steuben, Tippecanoe, Warren, Wayne, and Wells counties.

B. capillare [L.] Hedw. (Figs. 8-9.) Blackford, Jasper, Jefferson, Lake, Marshall, Martin, Monroe, and Porter counties.

B. cuspidatum (Br. and Sch.) Sch.[1] Carroll, Cass, Hamilton, Huntington, Jasper, Lagrange, Lake, Lawrence, Madison, Marshall, Monroe, Newton, Noble, Orange, *Owen, Porter, Putnam, Steuben, and Wells counties.

B. pendulum (Hornsch.) Sch.* (Figs. 10-11.) Carroll, Cass, Hamilton, Noble, Owen, and Warren counties.

Leptobryum

L. pyriforme [L.] Schimp. (Figs. 12-14.) Jasper, Lake, Monroe, Orange, Parke, Perry, Porter, Putnam, and Wayne counties.

Pohlia

P. nutans (Schreb.) Lindb. (Figs. 15-18.) Fountain, Hamilton, Jackson, Jasper, Lagrange, Lake, Marion, Marshall, Martin, Monroe, Noble, Owen, Perry, Porter, Putnam, *Steuben, Warren, *Wayne, and White counties.

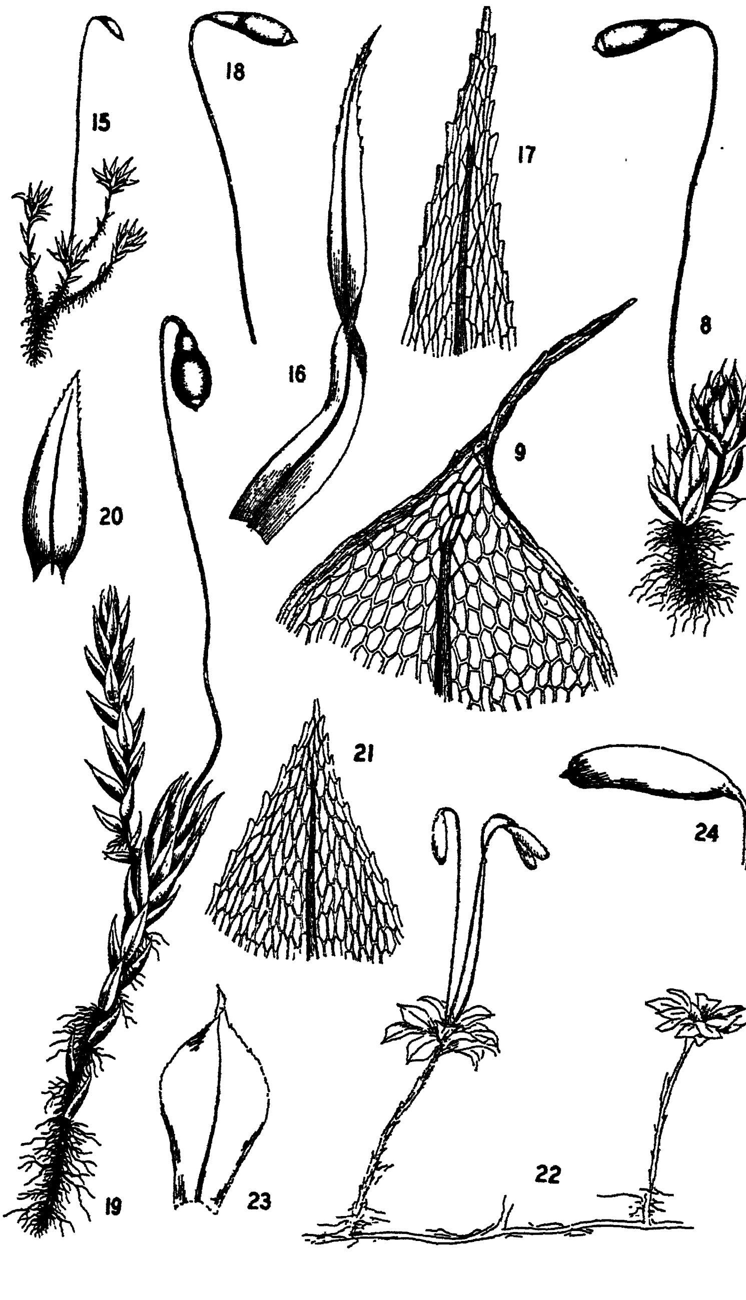
P. Wahlenbergii (Web. and Mohr) Andr. (*Mniobryum albicans* Limpr.) (Figs. 19-21.) Fountain, Huntington, Jasper, Jefferson, Jennings, Knox, Kosciusko, Lake, Madison, Martin, Monroe, Montgomery, Noble, Owen, Parke, Perry, Porter, Posey, Putnam, Sullivan, and Tippecanoe counties.

Rhodobryum

R. roseum (Weis) Limpr. (Figs. 22-24.) Carroll, Henry, Jasper, Jefferson, Jennings, Lake, Lawrence, Madison, Monroe, Noble, Orange, Owen, Perry, Porter, Putnam, Ripley, Steuben, Warren, *Wayne, and Wells counties.

Figs. 1-14. (All figures are from Grout, Mosses with Hand-lens and Microscope, unless otherwise indicated.) Figs. 1-2. *Bryum argenteum* (From fig. 115). Fig. 1. Capsule, X 20. Fig. 2. Leaf, much enlarged. Figs. 3-5. *Bryum bimum* (From pl. 47). Fig. 3. Gametophyte and sporophyte, much enlarged. Figs. 4-5. Leaf apices, much enlarged. Figs. 6-7. *Bryum caespiticium* (From fig. 113). Fig. 6. Gametophyte and sporophyte, much enlarged. Fig. 7. Leaf, much enlarged. Figs. 8-9. *Bryum capillare* (From pl. 48). Fig. 8. Gametophyte and sporophyte, much enlarged. Fig. 9. Leaf apex, much enlarged. Figs. 10-11. *Bryum pendulum*. Fig. 10. Peristome tooth and adherent segment, much en-

1. *Bryum intermedium* (Ludw.) Brid. has been reported as occurring in Indiana. According to A. L. Andrews, in Grout, Moss Flora of North America, this species does not occur in North America, and frequently the plants so determined are *B. cuspidatum*.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larged (From Grout, fig. 110). Fig. 11. Capsule, X 8 (From Dixon, Student's Handbook of British Mosses, pl. 42 C). Figs. 12-14. *Leptobryum pyriforme* (From fig. 105). Fig. 12. Gametophyte and sporophyte, X 2. Fig. 13. Leaf, X 10. Fig. 14. Capsule, X 10.

Figs. 15-24. *Pohlia nutans* (From fig. 107). Fig. 15. Gametophyte and sporophyte, much enlarged. Fig. 16. Comal leaf, much enlarged. Fig. 17. Apex of comal leaf, much enlarged. Fig. 18. Sporophyte, much enlarged. Figs. 19-21. *Pholia Wahlenbergii* (From pl. 46). Fig. 19. Gametophyte and sporophyte, much enlarged. Fig. 20. Leaf, much enlarged. Fig. 21. Leaf apex, much enlarged. Figs. 22-24. *Rhodobryum roseum* (From fig. 116). Fig. 22. Gametophyte and sporophyte, X 1. Fig. 23. Leaf, X 4. Fig. 24. Capsule, X 4.

CHEMISTRY

Chairman: KEITH SEYMOUR, Butler University

R. L. Hicks, Franklin College, was elected chairman for 1951.

ABSTRACTS

The changing character of the college undergraduate course in organic chemistry. G. B. BACHMAN, Purdue University.—The teaching of undergraduate organic chemistry is facing many of the problems met in the teaching of general chemistry a quarter of a century ago. These include especially:

1. Those problems associated with the development of "one semester" courses designed to fit into the crowded curricula of non-chemistry majors.

2. Those problems associated with a growing interest in the subject and the attraction to it of students with widely different backgrounds, objectives and attitudes.

3. Those problems associated with a rapidly expanding knowledge of the field in both its practical and theoretical aspects.

4. Those problems associated with a changing emphasis on the various phases of the subject.

The effect of these problems on the character of the course in undergraduate organic chemistry will be discussed and some of the experiences of the author described.

Problems in organic chemistry. JOHN H. BILLMAN, Indiana University.—One of the best ways to find out how well a student understands organic chemistry is to give him a large assortment of problems to work. These problems should be carefully chosen with the idea of illustrating basic facts and stimulating the students' interest in organic chemistry. Problems may be on nomenclature, the characterization and differentiation of compounds, the interpretation of data, and the synthesis of compounds from suggested compounds or from readily available reagents.

It is important to furnish answers to all of the problems so that the student may know if he is using the proper approach in solving problems and to give him confidence in himself.

The chlorination of aliphatic nitriles with phosphorus pentachloride. R. J. DEARBORN, Wabash College.—Aliphatic nitriles of the structure RCH_2CN may be converted to the corresponding α, δ-dichloronitriles in good yield by the action of phosphorous pentachloride, the other product of the reaction being phosphorus trichloride. Substitution does not

occur on any other carbon atom and only small amounts of the monochloro derivative are formed even when the quantity of phosphorus pentachloride used is reduced.

Phenylquinolines. C. E. KASLOW and MASON HAYEK, Indiana University.—This report concerns the preparation of several phenylquinolines; these substances were prepared for orientation studies in nitration work.

6-Phenylquinoline was prepared by means of a Skraup reaction on 4-acetamidobiphenyl while 8-phenylquinoline was obtained from 2-aminobiphenyl. The yields were 42 and 58% respectively.

The well-known Conrad-Limpach reaction was employed for the preparation of 6-phenyl-4-hydroxyquinaldine from 4-aminobiphenyl and methyl acetoacetate. 8-Phenyl-4-hydroxyquinaldine was obtained in a like manner from 2-aminobiphenyl. Ring-closure of p-phenylacetoacetanilide in mineral oil at 275° gave 6-phenyl-4-methylcarbostyril.

Condensation of 2- and 4-aminobiphenyl with ethyl ethoxalylacetate by well-known methods gave 8-phenyl- and 6-phenyl-4-hydroxy-2-quinolinecarboxylic esters, respectively. These were saponified and decarboxylated to yield the phenyl-4-hydroxyquinolines.

Each of the phenylquinolines were nitrated giving high yields but in most instances were mixtures of either mono- or polynitro compounds. However in the case of 6-phenylquinoline, it was shown that nitration gave 6-(p-nitrophenyl)-quinoline. Oxidation of the nitro compound gave a nitrobenzoic acid which did not depress the melting point of p-nitrobenzoic acid.

Vocational interests of graduate students in chemistry at Indiana University. LEROY H. KLEMM, Indiana University.—A survey of the vocational interests of graduate students in chemistry at Indiana University was made via questionnaire in the fall of 1947 and again in the fall of 1950. A total of 83 questionnaires were returned.

The major results found from the survey are as follows:

1. The age at which the students first decided to specialize in chemistry varied from a minimum of 10 years to a maximum of 25 years. Sixty-three per cent of the students, however, made this decision in the 16-19 age range.

2. Influences considered most significant to the fact that these students were in chemistry included: (a) courses taken in chemistry, (b) teachers, (c) general inclination toward science, (d) hobbies, (e) personal satisfaction in accomplishing new things, (f) scientist friends or relatives, and (g) the desire to work with their hands and minds simultaneously.

3. The ultimate primary goals in chemistry were principally academic (44% of the cases) and industrial (36%) work.

4. Those desiring academic work preferred small- to medium-sized institutions of the liberal arts college or general university type. Most

of them expected to teach undergraduate students. A majority expected to teach graduate students and to perform research themselves. Fewer expected to direct research of students or perform administrative work.

5. Those desiring industrial work preferred medium- to large-sized companies with moderate or vigorous research programs. Most of them expected to perform small scale laboratory research. Almost half of them expected to attain a position of group leader or director of research. There was little interest in routine laboratory work, sales, personnel work, and other such jobs.

6. Almost half of the students definitely desired or felt they might desire to pursue some other work in chemistry between graduation and entrance upon their ultimate vocational objectives. Chief among these intermediate plans were the holding of fellowships and the trying out of industrial work.

Titrimetric determination of magnesium. T. J. PHILLIPS and H. J. WILLIAMSON, Evansville College.—Excess fluoride is added to the magnesium solution and the excess backtitrated with aluminum chloride.

Allyl alcohol as a reagent for the detection of the mercurous ion. FRANK WELCHER, Indiana University (Indianapolis).—Allyl alcohol causes the immediate formation of a slate-gray precipitate when added to a solution of a mercurous salt containing dilute nitric acid. This reaction, which is fairly sensitive, is given by no other common ion. This reaction, therefore, appears to be a specific test for the mercurous ion.

Should Aliphatic & Aromatic Chemistry be taught separately? FRANK WELCHER, KENNETH WHELAN, and JEAN SISKELL, Indiana University (Indianapolis)—Proficiency in the study of organic compounds is acquired by a knowledge of the relationship between structure and properties. The principle of homology is based in part on the idea that compounds possessing common structural units are prepared similarly and react similarly. Since, in many cases the presence of a benzoid ring in an organic molecule exercises a profound effect upon the properties of the latter, it appears that the so-called aromatic hydrocarbons and their derivatives should be considered in a sense as a separate "homologous series". The alternative treatment is, of course, to consider all halogen derivatives of hydrocarbons at one time, aliphatic and aromatic compounds alike and to emphasize their similarities and differencies. The decision to consider aromatic and aliphatic compounds separately, regardless of the functional groups which they may possess, is based upon the belief that such practice leads to a simpler presentation of the subject matter of organic chemistry, and readier understanding of it.

The Effect of 1, 3, 7-Trimethyl and 1, 3, 7, 9-Tetramethyl Uric Acids on Uric Acid Excretion in the White Rat

HAROLD J. BLUMENTHAL and RALPH C. CORLEY, Purdue University

The main end product of purine catabolism in the rat is allantoin, formed by the action of the enzyme uricase, an aerobic dehydrogenase, specific for uric acid (7). A small amount of uric acid is regularly excreted. The effect of many substances in changing the rate of excretion of uric acid and allantoin has been reviewed by Martin (8).

In their studies on the properties of uricase *in vitro*, Keilin and Hartree (7) reported that of the 16 mono-, di-, or tri-methylated or ethylated derivatives of uric acid tested, none were oxidized by the enzyme, although these compounds did inhibit the initial rate of oxidation of uric acid from 16 to 68 per cent. It has seemed of interest to determine whether the great inhibitory effect of 1, 3, 7-trimethyl uric acid *in vitro* might be demonstrable *in vivo* in the white rat, as evidenced by a change in the amount of uric acid excreted. The relatively great solubility and solubilizing effect of 1, 3, 7, 9-tetramethyl uric acid (10) suggested its inclusion in this study.

Experimental

The trimethyl uric acid (TRMUA) and tetramethyl uric acid (TEMUA) were synthesized from caffeine. The 8-chlorocaffeine was prepared according to the method of Fischer and Reese (3) and converted to 8-methoxycaffeine by a slight modification of the procedure of Huston and Allen (5). The TRMUA obtained by splitting the methoxy group with 50 per cent hydrochloric acid at 55-70°C. for 30 minutes melted sharply at 345°C., in agreement with the value in the literature (1). TEMUA was obtained by rearrangement of 8-methoxycaffeine in an open tube, similar to the procedure of Huston and Allen (6). The TEMUA thus obtained melted at 227-229°C. which agrees with the value 228°C. reported in the literature (1). The sodium salicylate, an Eastman product, was used without further purification.

The experimental animals were adult male albino rats maintained *ad libitum* on a Purina Chow diet. The animals were housed in separate metabolism cages and the 24 hour urine samples were collected under toluene. The urine and funnel washings were refrigerated until the time of analysis. Analyses were generally started within 24 hours after collection.

Compounds administered orally were mixed with the Purina Chow. Materials administered intraperitoneally were dissolved in double distilled water. If more than 10 ml. had to be injected in one day, divided doses several hours apart were used.

The uricase method (2) was used to estimate true uric acid. Transmittancy was measured with a Cenco-Sheard-Sanford filter photo-

meter using a red filter. The dilutions used during the analyses of experimental urines were kept the same as those used during the control analyses. Each animal served as its own control. The 24 hour uric acid values for three or four days preceding the administration of the experimental compound were averaged to obtain the control value for uric acid for each animal.

Results and Discussion

The average amount of uric acid excreted daily was usually reasonably constant in the successive experiments with each rat, although the excretion from day to day at times showed wide fluctuations, probably attributable in some instances to incomplete voiding of the urine on some days to which samples were referred, and to extra elimination on the days following.

Table I presents a summary of the results. In the concentrations used, TRMUA administered, orally or intraperitoneally, had no consistent effect on the excretion of uric acid as evidenced by the average values obtained, (Series 1 and 2). The intraperitoneal injection of

TABLE I. The effect of two methylated uric acids, with or without salicylate, on the urinary excretion of uric acid.

Series	Number of rats	Average control uric acid	Exptl. days	Average exptl. uric acid	Per cent change	Compound Administered
		mgm.		mgm.		mgm.
1	11	2.72	4	2.80	+ 2.9	50 to 500 TRMUA; oral on days 1 or 1 and 2
2	12	2.80	4	2.78	— 0.7	50 to 150 TRMUA; i.p. at various times
3	13	3.63	4	3.00	— 17.4	50 TEMUA; i.p. on days 1 and 2
4a	2	3.66	2	7.79	+112.8	70 SS; i.p. each day
4b	3	3.78	2	6.00	+ 58.8	70 SS and 60 TEMUA; i.p. each day
5a	2	3.97	1	6.70	+ 68.8	78 SS (av.); i.p.
5b	3	4.18	1	6.27	+ 50.0	78 SS (av.) and 56 TEMUA; i.p.
6	5	4.32	4	3.26	— 24.5	60 TEMUA; i.p. each day
6a	2	4.63	3	5.90	+ 27.6	70 SS; i.p. each day for next 3 days
6b	3	4.01	3	3.79	— 5.5	70 SS and 60 TEMUA; i.p. each day for next 3 days

TEMUA=1,3,7,9-tetramethyl uric acid
TRMUA=1,3,7-trimethyl uric acid
SS=sodium salicylate
i.p.=intraperitoneal

TEMUA was followed by a decreased excretion of uric acid in sixteen of the eighteen individual experiments (Series 3 and 6).

As the observations with TEMUA can not be related in an obvious way to the action of uricase, a relation with excretion is suggested. Sodium salicylate is known to increase the excretion of the uric acid (cf. Friedman, 4). TEMUA was found to decrease this effect of salicylate (Series 4, 5, and 6). These results are in accord with those of Quick (9) who found that "the stimulating action of salicylate and other substances could be inhibited by ingestion of 'depressing substances'". This same effect was shown in Series 6a even after an initial decrease in urate excretion following administration of TEMUA for four days.

No clear explanation appears for the effect of TEMUA in decreasing the excretion of uric acid. Inhibition of the action of uricase observed *in vitro*, or inhibition of some specific mechanism for the reabsorption of uric acid from the glomerular filtrate presumably would have led to an increase in the elimination of uric acid. However it is conceivable that TEMUA may exert an inhibition of the mechanism for active tubular excretion of uric acid if such exists in the white rat. Further work may provide evidence in this regard. Wolfson, Cohn and Shore (11) have shown the importance of tubular excretion of uric acid in the Dalmatian dog.

Conclusions

Administration of 1, 3, 7-trimethyl uric acid, either orally or intraperitoneally, had no consistent effect on the uric acid excretion of the white rat. 1, 3, 7, 9-Tetramethyl uric acid, however, when administered intraperitoneally caused a significant decrease in urate excretion. Concomitant administration of tetramethyl uric acid and sodium salicylate caused the level of urate excretion to remain below that of rats receiving salicylate alone. It is conceivable that the effect of tetramethyl uric acid in decreasing the excretion of uric acid is associated with an inhibition for active tubular excretion of uric acid.

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Some Elementary Physical and Chemical Processes in Radiobiology[1]

MILTON BURTON, University of Notre Dame

Some significant facts of radiobiology may be summarized in the following simplified terms. Irradiation of biological material under suitable circumstances causes mutations. These mutations are changes detectable in terms of the tests we apply. For lower organisms the test most applied is lethality or inability of the entity to procreate. A negative test means that at least one function of the entity responsible for reaction to the test applied is adversely affected. In turn, adverse response reflects damage in the particular part or parts of the total chemical structure of the biological entity responsible for the effect observed. A mutation observable by a particular test signifies damage affecting a particular prosthetic group. Unless the damage affects that group, the test indicates no damage to the entity. The latter conclusion is, of course, incorrect. A negative test means only no perceptible damage detectable by the test applied.

The effect of the radiation is not necessarily directly on the biological entity adversely affected thereby. On the macroscopic scale the radiation may produce persistent products poisonous to the organism. On a microscopic scale the radiation may produce transient phenomena or chemical entities in the ambient fluid which are potentially highly damaging to the biological entity.

In this paper we confine ourselves to elucidation of the simpler phenomena of radiobiology in terms of elementary physical and chemical processes. Consequently, our considerations are applicable only to very simple biological entities or particles, e.g., minimum fragments of virus responsive to test, bacteriophage, etc. Furthermore, we limit ourselves to effects labelled "microscopic" in the preceding paragraph, where the radiation acts either directly in the biological particle or, indirectly, chemically or physically in an interval of time not much greater than a microsecond. We are not concerned, for example, with radiation-induced changes in the nutritional environment of a biological particle.

Even on such a rudimentary scale of radiobiology, however, there are apparently secondary effects. If oxygen is removed from a biological fluid, the material becomes less sensitive to x or gamma radiation; the mean lethal dose may be many times increased. A similar effect is obtained by incorporation in the fluid of certain reagents such as cysteine, certain sugars, and hydrogen cyanide. (11). The existence

[1]A contribution from the Radiation Chemistry Project, operated by the University of Notre Dame under Atomic Energy Commission contract No. AT (11-1)-38.

of such "protective agents" and the mechanism of their protection is a matter of primary concern.

Mathematical analysis of the effects of irradiation on a biological suspension indicates that the individual effect of the irradiation particle is principally via ionization rather than excitation, that a single hit within a sensitive volume or "target" is in many cases sufficient to produce a detectable (e.g., lethal) effect, that the target is in general smaller than the biological entity (as measured in electron microscopic examination of the dry entity), that this negative deviation of target size increases with increased size of entity, but that nevertheless low-velocity bombarding particles give a larger computed target than fast particles. It is the purpose of this paper to show that our present knowledge of elementary processes of radiation physics and radiation chemistry is consistent with these facts of radiobiology and that parallel to the purely mathematical model of the "target theory" a consistent chemical model can be constructed.

Physical Effects

The elementary physical effects of radiation are summarized in Table I. The major effect of x or gamma radiation is produced by the fast electrons ejected. A single 1 Mev electron ejected in a Compton recoil may be responsible for more than 30,000 subsequent ionization and 30,000 excitation processes. Thus, the primary effect of the radiation is chemically insignificant. A similar statement applies to the primary effect of the neutrons. Most of the resultant chemical effects in water, for example, are explicable in terms of action by the proton expelled from a parent molecule by the neutron.

TABLE I. Physical Effects of Radiation

Radiation	Process	Primary Effect	Distance between Primary Effects
X or gamma	Principally Compton effect	Electron expulsion	Only 1 effect per photon
Neutrons	Nuclear collision	Atom expulsion plus ionization plus excitation	Dependent on nuclear cross-section for neutron of velocity v
Charged particles	Interaction with electronic atmosphere	Ionization and excitation	For slow particles: $\sim$ 5-10 molecules. For fast particles: $\sim$ 100-500 molecules

A charged particle interacts with the electron cloud around an atom or molecule and produces quantized displacement corresponding to some state of excitation or ionization. The degree of interaction depends on the time available for the process and the distance of closest approach. The greater the time available, the greater the distance at which perceptible interaction occurs. For slow particles of high energy (such as protons, deuterons, or alphas) the cross-section for interaction is much greater than for fast particles of equal energy (i.e., electrons). Consequently, the distance between successive ionizations (or excitations) may be about 5-10 molecules for the former and about 100-500 molecules for the latter. In the radiation chemistry of water these primary physical effects are reflected in essential differences in chemical effects.

Many physical effects are secondary but, nevertheless, more important contributors to the total effect than the primary process. Thus, electrons ejected in photon absorption or by Compton recoil are responsible for most of the effect of x or gamma rays. Electrons (delta rays) ejected in charged particle interaction with atoms or molecules are directly responsible for a major part of heavy particle effects. Protons ejected by neutron bombardment in water are responsible either directly or indirectly (i.e., via energetic electrons) for most of the effects observed.

Two other important classes of phenomena must be mentioned in the physical category. They are ionization transfer and excitation transfer. We write schematically as possible alternative first steps[2]

$$A \begin{array}{l} \nearrow A^{+} + e \\ \searrow A^{*} \end{array}$$

where either positive ions or excited molecules are produced. Consider a mixture containing also the species B. Then, also

$$B \begin{array}{l} \nearrow B^{+} + e \\ \searrow B^{*} \end{array}$$

If the ionization potential of A is greater than the ionization potential of B (i.e., $I_A > I_B$), then the reaction

$$A^+ + B \rightarrow A + B^+ + \text{energy}$$

occurs with high probability particularly in condensed systems. On the other hand, the possibility of energy transfer such as

$$B^* + A \rightarrow A^* + B$$

or the reverse is determined by considerations which may be more restrictive.

Chemical Effects

We are concerned principally with effects of significance in biological systems. Consequently, we shall treat successively water, organic substances and aquo-organic systems.

Water.—The radiation chemistry of water has been summarized principally by Allen and his co-workers (1, 2). We follow the ideas employed by them. The principal reactions are

$$H_2O \rightsquigarrow H_2O^+ + e \qquad 1.$$
$$H_2O^+ + aq \rightarrow H_3O^+ + OH \qquad 2.$$
$$H_2O + e \rightarrow H + OH^- \qquad 3.$$
$$OH + OH \rightarrow H_2O_2 \qquad 4.$$
$$H + H \rightarrow H_2 \qquad 5.$$
$$OH + H \rightarrow H_2O \qquad 6.$$

The excitation processes in water are not important in biological systems. As we have seen, the distance between successive ionizations in water is small for slow-moving particles, large for fast-moving particles. In consequence, under deuteron irradiation for example, free OH radicals are formed relatively close together and reaction 4 is probable. On the other hand, under electron or x-irradiation production of H_2O_2, or of oxygen formed by its decomposition, is perceptible only with great difficulty.

Free OH radicals disappear not only by formation of hydrogen peroxide and in the back reaction 6 but also by a chain process involving the products of reactions 4 and 5.

$$OH + H_2 \rightarrow H_2O + H \qquad 7.$$
$$H + H_2O_2 \rightarrow H_2O + OH \qquad 8.$$

Any process which interrupts the repeated sequence 7, 8 promotes the yield of hydrogen peroxide. Thus, although hydrogen peroxide cannot be formed in conveniently measurable concentration in radiolysis of pure water by electrons or x rays, introduction of a small amount of oxygen promotes such production because of the reaction

$$H + O_2 \rightarrow HO_2 \qquad 9.$$

This reaction is not only a first stage on the path to formation of H_2O_2 (e.g., by H atom capture) but also interrupts chains such as 7, 8 responsible for back reactions in which H_2O_2, H and OH revert to water without appearance of detectable products.

For our present purpose our interest in reaction 9 is that thereby a very active entity, free H, is removed from solution and replaced by a less active (reducing or oxidizing) entity HO_2. Simultaneously, reactions available for disappearance of the active entity OH are more restricted and that active oxidizing entity consequently persists longer.

Long persistence of a radical such as HO_2, or OH in its presence, means that it has a greater diffusion range. We shall see that in radiobiology many of the effects produced by radiation occur via free radicals. Thus, any process such as reaction 9, which increases diffusion range of radicals produced in the elementary chemical processes, effectively increases the size of the sensitive volume or "target" involving the biological entity. The H_2O_2 formed in reaction 4 is itself more persistent than the parent OH radicals and may consequently be responsible for greater target size in heavy-particle irradiation.

Organic substances.—Let us consider first the reaction

$$A \rightarrow A^* \qquad 1.$$

The molecule A^* may subsequently decompose but the locus of decomposition, as shown by photochemical studies, e.g. of aldehydes and ketones, is not necessarily the locus of primary excitation (12). It is not necessarily true that reaction 1 lead to a decomposition

$$A^* \rightarrow R + X \qquad 2.$$

In particular, where product radicals are large, a Franck-Rabinowitch cage effect (7) may reduce yield and even prevent it in condensed systems. Furthermore, there is evidence (such as in the alkyl benzenes) that excitation in a labile group may be transferred into a resistant portion of the molecule and dissipated without chemical effect (5, 8, 13).

An excited molecule is produced not only directly, as in reaction 1, but indirectly, as in the sequence,

$$A \rightsquigarrow A^+ + e \qquad 3.$$

$$A^+ + e \rightarrow A^{*\prime} \qquad 4.$$

Although the states of excitation of A^* and $A^{*\prime}$ differ, cage effects and protection effects, by resistant groups to which energy may be transferred, can still occur.

Where we deal with a mixture of organic substances we must not neglect the possibility of ionization transfer. Thus, the reaction

$$A^+ + B \rightarrow A + B^+ + \text{energy} \qquad 5.$$

already mentioned can transfer ionization from a labile to a non-labile part of a biological entity or vice versa. In other words, the site of the chemical effect need not be the site of the absorption act. Conversely, the existence of an inert group may serve to protect a labile group at a distance. Evidence for such phenomena has been adduced for interaction between groups in alkyl benzenes (8, 13).

Thus, we find that in organic compounds and mixtures of organic compounds such as may exist in biological entities, energy absorbed at a particular locus may be effective at a more remote point or may be made ineffective by transfer to, and dissipation in, a less reactive group (e.g., a benzene ring). It follows, since a good portion of a complex mixture may be relatively inert to high-energy radiation that the sensitive volume may be much less than the total volume. Furthermore, if the reaction involves a rupture process 2, perceptible product formation may occur only when cage effects are unimportant; i.e., near the surface of the aggregate involved. We must also take into consideration the fact that although a chemical change may occur a prosethetic group may not be involved. From these elementary considerations, it follows not only that the radiation-sensitive volume (measured by a particular test) of a molecular aggregate may be less than the true volume but that the ratio of radiation-sensitive volume to true volume may decrease with size of aggregate. The latter effect will in turn be exaggerated in any case where there is a natural tendency for the relative amount of inert material to increase with size of the aggregate.

Aquo-organic systems.—The ionization potential of liquid water is most probably <7.4 ev (4) while organic compounds have somewhat higher ionization potentials in aqueous dispersion. It has been shown (3) that under such conditions, if we designate the organic material by A, an important sequence of reactions involving primary ionization of A in aqueous suspension is

$$A \rightsquigarrow A^{+} + e \qquad 1.$$
$$A^{+} + H_2O\ aq \rightarrow A + H_3O^{+} + OH \qquad 2.$$

Thus, the result of a primary ionization in A may be the formation in immedately adjacent water of an H_3O^+ ion and the active hydroxyl radical. Furthermore, after thermalization of the electron, the neutralization process

$$A^{+} + e \rightarrow A^{*} \qquad 3.$$

competes with the process (3, 10)

$$H_2O + e \rightarrow H + OH^{-} \qquad 4.$$

which also occurs immediately adjacent to the organic aggregate. Thus, even when the primary radiation process occurs in an organic aggregate, the chemical process may involve interaction of the aggregate with one of the highly active entities H, OH, H_3O^+, or OH^- characteristic of the radiation chemistry of water.

Radiobiology

We have seen from the properties of water and aqueous systems that radiation absorbed in a region sufficiently close to a biological entity may cause damaging effect because of interaction with that entity of free hydrogen atoms or hydroxyl radicals resultant in an early stage of the radiolysis of water. Since heavy particles produce high local concentrations of hydroxyl radicals in water (with resultant increased probability of hydrogen peroxide production) the diffusion range of the active entities may be somewhat greater than in electron, x or gamma irradiation of water. Thus, the sensitive volume or target size is somewhat greater for heavy-particle bombardment.

When oxygen is present in water, it traps atomic hydrogen by the reaction

$$H + O_2 \rightarrow HO_2$$

The hydroperoxyl radical thus produced is less active, and therefore, more persistent, than H or HO_2 and consequently has a much greater diffusion range. Thus, oxygen tends to increase the sensitive volume (in the neighborhood of a biological entity) or the target size and the lethality of the radiation. However, this effect is significant only in light-particle irradiation, not in heavy-particle phenomena. The explanation is given by Dainton (6) and by Magee (9) who concluded that in order for a solute to be effective in reactions with intermediates produced in the ionization column (of high-energy radiation) it must

be present in concentration of the same order as that attained by the intermediates in the column. Such a concentration of oxygen is easily achieved in fast-particle irradiation, where radical products are about 100-500 molecules apart. It is practically unattainable when the radicals are produced only 5-10 molecules apart.

The method of testing the effect of radiation on biological material ensures that a significant fraction of the effects may be undetected. Only those effects in a prosthetic group, responsive to the method of testing, are found. Furthermore, not all parts of the entity are equally sensitive to radiation, some parts may be inert, and cage effects may prevent observable chemical change in other parts. The total effect is to make the mathematically calculated target size considerably less than that of the entity. This situation is true in spite of the fact that the sensitive volume includes a portion of the aqueous medium adjacent to the entity. Thus, the calculated target is not to be identified with the biological entity and, in spite of the fact that the sensitive volume includes water, is smaller than the entity.

Summary

Simple observations of radiobiology, particularly relating to target theory, the effect of oxygen, and inhibition of oxygen effects, are explicable in terms of elementary physical and chemical processes of radiation chemistry. The target is not identified with the biological entity. The latter and the ambient fluid are included in the target but the biological entity is not uniformly sensitive. The sensitive volume of fluid is determined by the range of effective radicals produced therein. The free radicals H and OH are extremely active but, consequently, have a small diffusion range. Presence of oxygen causes entrapment of free H to give the less active, and therefore longer range, free radical HO_2. Oxygen increases target size for, and therefore lethality of, x or gamma radiation but no oxygen effect is possible with heavy-particle bombardment within the ordinary range of oxygen pressures. Lethality of oxygen-containing solutions may be decreased by introduction of protective agents, oxidizable by HO_2 but not by oxygen.

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Some Schiff Bases of N-Methyl-4-carbostyrilcarboxaldehyde

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Several studies have been reported on the preparation and properties of N-substituted-4-methylcarbostyrils (1), (2), (3). We have been interested in the substitution of various groups on the 4 position of 1, 4-dimethylcarbostyril by the conversion of the 4-methyl group to a formyl group with selenium dioxide and the subsequent production of a number of derivatives from this aldehyde.

With the intention of continuing this study, we have prepared a number of Schiff Bases of 1-methyl-4-carbostyrilcarboxaldehyde which we hope to use as intermediates for further study. It is the purpose of this paper to report the preparation and properties of these anils.

Similar compounds produced from quinoline-4-aldehyde and several different aromatic amines have already been reported by Ramsey, Baldwin and Tipson (4). It is interesting to note that compounds prepared by us are quite similar in physical properties to the compounds reported by these authors.

The anils prepared are those obtained by the condensation of 1-methyl-4-carbostyrilcarboxaldehyde with p-aminophenol, p-diethylaminoaniline, p-aminobenzoic acid, p-aminobenzenesulfonamid, and p-aminoazobenzene. These compounds were all obtained in yields of 76-98 percet by condensation of the amine and aldehyde in boiling alcohol for eighteen hours.

One of these compounds, 1-methyl-4-carbostyrilcarboxaldehyde p-phenylazoanil, has the properties of an indicator dye. It has been found to give a brown-red color in acid solution with a definite change to light green when the solution is made basic with ammonium hydroxide or sodium hydroxide. Further study is contemplated to find the pH range of this color change.

These compounds offer a convenient method for the introduction of substituents in the carbostyril nucleus at the 4 position.

Experimental

1-Methyl-4-carbostyrilcarboxaldehyde (I) was prepared as previously described in this journal (3). The necessary substituted anilines were all Organic Chemicals obtained from the Distillation Products Industries, Rochester, New York. The melting points listed for these compounds were all taken on a Fisher-Johns Melting Point Block.

1-Methyl-4-carbostyrilcarboxaldehyde p-Hydroxyanil.—Two and nine-tenths grams (.0265 moles) of p-aminophenol was dissolved in 75 ml. of absolute alcohol with heating. This solution was filtered and a

[1] The writer wishes to thank Mr. Harvey Flanders who assisted him in the preparation of these compounds.

solution of 5 g. of I dissolved in 40 ml. of ethanol was added to it. This mixture was refluxed on the steam bath for 18 hours. When cooled in the refrigerator, the crystalline product formed and was recovered by filtration. The product weighed 7.2 g. (98%). A 0.5 g. sample was recrystallized from 30 ml. of ethanol which on cooling gave bronze colored crystals. This product melted at 234-236°.

Anal.

Calc'd for $C_{17}H_{14}N_2O_2$: N, 10.1%
Found: N, 10.5%

1-Methyl-4-carbostyrilcarboxaldehyde p-Diethylaminoanil. — In a manner similar to that described for the preceding preparation, 2.2 g. (.0132 moles) of p-diethylaminoaniline was dissolved in ethanol and treated for 18 hours with 2.5 g. (.0132 moles) of I. Upon cooling small flat red plates were collected. Five tenths of a gram of this substance was recrystallized from 30 ml. of ethanol. Orange crystals were recovered which melted at 171-172°. The total yield was 4.0 g. (91%).

Anal.

Calc'd for $C_{21}H_{23}ON_3$: N, 12.7%
Found: N, 12.6%

1-Methyl-4-carbostyrilcarboxaldehyde p-Carboxyanil.—In a like manner 1.81 g. of p-aminobenzoic acid (.0132 moles) was treated with 2.5 g. of I. After refluxing for 18 hours, the product was obtained as fine pale yellow crystals. The yield was 3.1 g. (76%). This compound was recrystallized from ethanol and gave a m.p. of 263.5-264.5°.

Anal.

Calc'd for $C_{18}H_{14}N_2O_3$: N, 9.15%
Found: N, 8.83%

1-Methyl-4-carbostyrilcarboxaldehyde p-Sulfonamidanil.—Two and two-tenths grams (.0132 moles) of p-aminobenzenesulfonamid was treated with 2.5 g. of I in ethanol as described in the preceding preparations. The product was recovered as yellow crystals which melted at 257-258°. The yield was 4.4 g. (98%). Upon recrystallization the compound melted at 261-262°.

Anal.

Calc'd for $C_{17}H_{15}N_3O_3S$: N, 12.31%
Found: N, 11.98%

1-Methyl-4-carbostyrilcarboxaldehyde p-Phenylazoanil. — The same general procedure was followed as in the preparation of the other anils. Two and six-tenths grams of the p-aminoazobenzene (.0132 moles) was reacted with 2.5 g. of I. After refluxing, a green-brown solid was obtained which weighed 4.7 g. (97%). This substance, when crystallized twice from ethanol, was obtained as orange crystals which had a softening point at 91° and melted at 97-99°.

Anal.

Calc'd for $C_{23}H_{18}N_4O$: N, 15.3%
Found: N, 14.7%

Summary

Several Schiff Bases of 1-Methyl-4-carbostyrilcarboxaldehyde have been prepared and described. These compounds can be used for starting materials in the preparation of 4 substituted carbostyrils.

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A Modified Starch-Iodine Method Suitable for the Study of Starch and its Hydrolysis Products

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A method of extracting excess iodine from the starch-iodine complex by carbon tetrachloride has been developed which produces a color only with the amylose present, removes turbidity due to insoluble or retrograde amylose, and is not interfered with by amylopectin or lower dextrins. By this method some new insight can be gained into the mechanism of starch degradation.

Varying quantities (1 to 5 ml. of 0.0125 to 2.0% solutions) of starch solutions were added to 25 ml. Folin-Wu tubes which had been provided with 3 ml. each of an iodine solution (0.05% iodine solution in 0.15% potassium iodide and 0.5% hydrochloric acid). Distilled water was added, 10 ml. to each tube, and the solutions were mixed by inversion. Carbon tetrachloride was then added, 5 ml. to each tube, the tubes were shaken 50 times, diluted to 25 ml., mixed again by inversion, and allowed to settle for 20 minutes. The absorption spectra of the supernatant liquids were then determined, against a standard of distilled water, by means of a Beckman DU spectrophotometer.

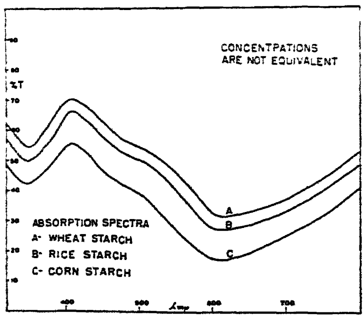
The carbon tetrachloride layer emulsifies when shaken with starch. Apparently this is due to the adsorption of a kind of retrograde amylose, since the adsorbed material will not dissolve after being shaken in repeated changes of distilled water, forms a blue color on the surface of the carbon tetrachloride droplets when iodine is added, and will dissolve in 0.1 N sodium hydroxide to form a solution which, when neutralized, produces a color the spectrum of which is identical with that of amylose. The ability to form this emulsion disappears during the early stages of hydrolysis.

The method has been found to be quite reproducible and the quantities of iodine and carbon tetrachloride are not critical. Beer's law has been found to be followed at 610mμ, over the range 0.2% to 0.025% starch. The color produced is related only to the amount of amylose present and is independent of the iodine concentration. This is shown by the variation of the transmittancy at 350 mμ (due to iodine alone) in direct relationship with the transmittancy at 610 mμ (that due to amylose-iodine complex and which depends upon the amount of amylose present). This permits a comparison of the color developed with excess iodine to the color produced with that amount of iodine utilized in the actual amylose-iodine absorption complex, and thus additional information can be obtained concerning the qualitative and quantitative changes occurring during the early stages of starch degradation.

Curves for three types of whole starches were prepared, corn starch, rice starch, and wheat starch (Fig. 1). The shapes of these curves were

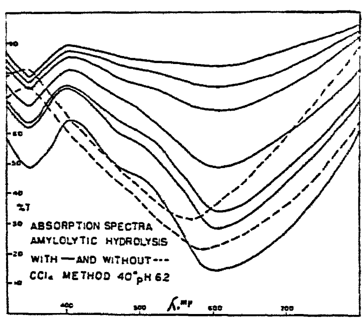
alike, including the position of maximum absorption at 610 mμ, and they correspond closely to the curves prepared by Simerl and Browning from crystalline corn amylose (3). The slight difference is probably due to the difference in standards used.

The hydrolysis experiments were performed with a sample of amylose prepared from rice starch by the method of Schoch (2).



Aliquots were removed from the hydrolysates at suitable time intervals and absorption spectra were run both with and without shaking with carbon tetrachloride.

Hydrolysis of amylose by beta-amylase produced substances, the spectra of which were similar throughout the range which could be followed, and there was no apparent shift in the position of the maximum absorption (Fig. 2). However, curves produced from these

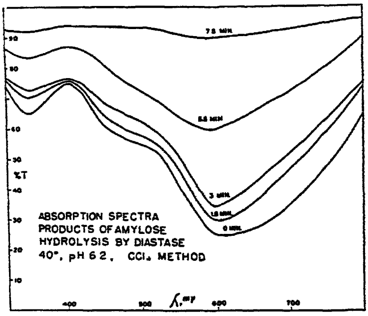


iodine complexes without extraction by carbon tetrachloride showed a definite shift in the location of the maximum toward the blue end of the spectrum.

The spectra of the hydrolysis products resulting from the action of malt diastase showed a continually changing picture and a progressive shift of the position of the maximum both before and after extraction with carbon tetrachloride (Fig. 3). The transmittancy increased steadily in both cases. Such a shift has been previously reported by Hanes and Cattle (1) and by Swanson (4). This latter paper in addition to

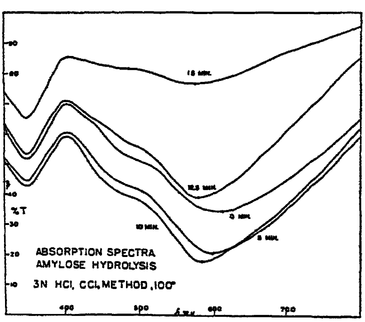
numerous others, indicates that this phenomenon is due to the appearance of increasingly shorter dextrins.

Acid hydrolysis (100° C, 0.3 N HCl) appeared to be much the same as hydrolysis by diastase except that there was a marked increase in the



apparent concentration of higher dextrins and a simultaneous shift in the position of the maximum immediately after bringing the mixture to boiling temperature (Fig. 4).

The fact that the position of maximum absorption did not change during hydrolysis by beta-amylase and after extraction with carbon



tetrachloride indicates the presence of unhydrolyzed amylose. At the same time very short chain dextrins are undoubtedly present as indicated by the shift in the location of the maximum when determined without extraction. The co-existence of these two types of molecules, at any given time after hydrolysis has started, infers the formation of a tightly bound enzyme-substrate complex in which the enzyme remains tightly bound until the macromolecule is reduced to a very short dextrin. Such a complex has been previously postulated by Swanson (4) for this enzyme.

The sudden increase in apparent concentration at the start of acid hydrolysis is believed to be due to the splitting of very long molecules near their center to produce dextrins of a sufficient length to increase the apparent color intensity. This phenomenon does not occur in

enzymatic hydrolysis, nor is it reported to occur during acid hydrolysis at 30° C. (4).

Although no quantitative studies have been presented here, it is felt that this method might well be adapted to the study of the kinetics of starch degradation, the determination of bound iodine, and the estimation of the amylose content of whole starches.

Summary

A method for studying the absorption spectrum of the amylose iodine complex in the presence of amylopectin has been described.

The method has been applied to study the hydrolysis of amylose. The results suggest that beta-amylase progressively hydrolyzes each amylose molecule until a very short dextrin molecule results, whereas acid hydrolysis initially breaks the molecules of amylose into large fragments.

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The Precipiation of Calcium Carbonate[1]

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The formation of calcium carbonate by chemical precipitation has been the subject of a number of investigations because of the commercial importance of this material in the pigment, sugar and paper industries. In the course of published researches, a few anomolous situations have arisen and much of the data has been treated only empirically. It is the purpose of the present study to investigate the precipitation of calcium carbonate in light of our present concepts concerning the formation of precipitates.

Calcium carbonate precipitates, under proper conditions, in one or more of three forms: calcite; aragonite; vaterite. Faivre has studies this precipitation process by mixing aqueous solutions of sodium carbonate and calcium chloride, with a view toward determining which form predominates as a function of temperature of formation (1). He reported that below 60° C. vaterite is always formed, but that this modification is very unstable and is rapidly transformed to calcite so that pure calcite can be separated after a reasonable aging period. He did succeed in isolating vaterite by rapid separation from an alcoholic precipitation medium. Faivre further reported that pure aragonite can be obtained at 60° C., while a calcite-aragonite mixture appears above 60° C. Lucas reported that both aragonite and vaterite revert to calcite unless kept dry (2). Noda confirmed the formation of aragonite at elevated temperatures (3). It may be noted that the function of temperature in determining the crystal form of precipitated calcium carbonate has been investigated thoroughly, but that little attention has been paid to the precipitation medium and time of aging and no attention to pH.

Spengler reported that in all cases a primary floccular substance is first formed which immediately begins transformation to one of the crystalline forms (4). Ephraim assumes the floccular material to be amorphous (5).

A number of industrial processes for the formation of fine particles of calcium carbonate have been reported, chiefly in the patent literature. In general, small particles have been obtained by some combination of the following: temperature below 40° C.; pH above 8; rapid addition of more concentrated reagent to more dilute one; digestion time as short as possible.

Experimental

The calcium carbonate samples were prepared by direct mixing of solutions of calcium chloride and sodium carbonate, each with the

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desired combination of conditions and concentrations. Temperature control was achieved with a water bath regulated within one-half degree of the desired temperature. A Beckman pH Meter was employed for all pH measurements. Electron microscope observations were made with an RCA type EMU instrument, and x-ray diffraction patterns were made with a Hayes instrument.

Each precipitate-suspension was centrifuged once and the supernatant decanted prior to electron microscope observation to rid each sample of dissolved material which would otherwise contaminate the crystals. Specimens were mounted on specially prepared formvar films

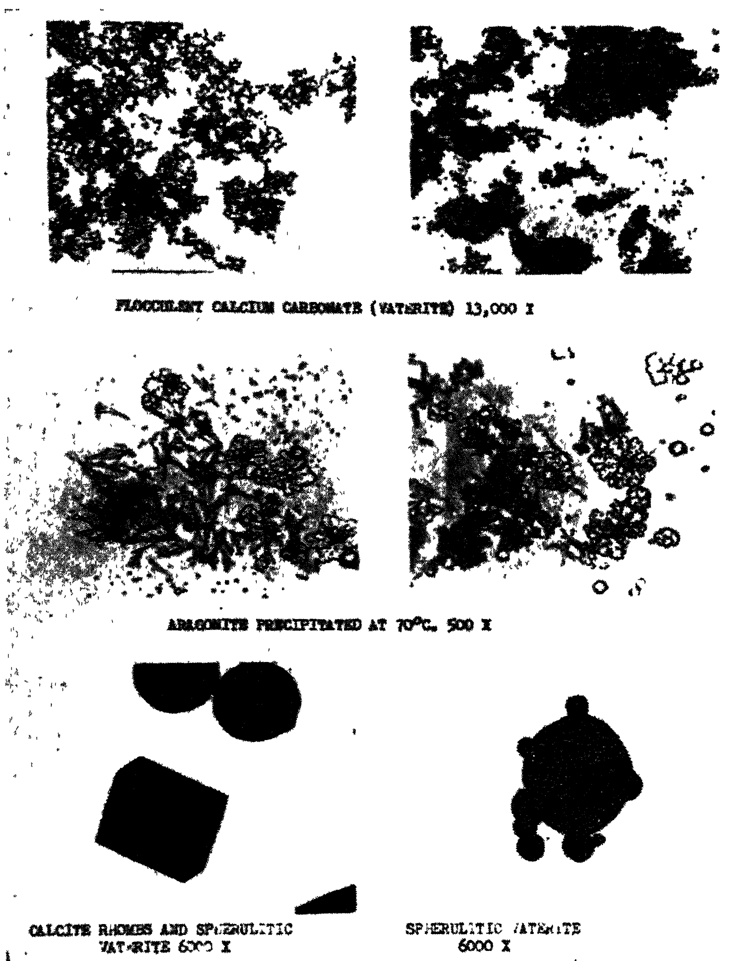

Fig. 1. Micrographs (middle row light micrographs; other electron micrographs)

which were in turn supported by standard 200-mesh nickel grids. The entire mounting procedure, from the time of mixing reagents to the time of completion of the mounting for final observation, took less than five minutes except, of course, in those cases when a controlled aging period was purposely introduced prior to mounting.

Results with Discussion

Crystal Form. The crystal form of precipitated calcium carbonate was investigated in so far as it is determined by the medium from which precipitated, the time of aging in the mother liquid, the pH at the time of precipitation and the temperature of formation from aqueous medium.

1. Medium from which precipitated. An alcoholic medium distinctly favored the formation of a flocculent material with only a trace of other forms. X-ray diffraction patterns of this material showed that it is not merely an amorphous material, but rather that it is finely divided crystalline vaterite. From water, calcite, calcite plus aragonite, aragonite, or calcite plus vaterite appeared, depending upon the temperature. Micrographs are shown in figure 1, while the x-ray data is summarized graphically in figure 2. The vaterite floc consists of chain-like units of varying length, each chain consisting of small circular particles, seemingly with less dense material holding them together. The small particles appear spherulitic.

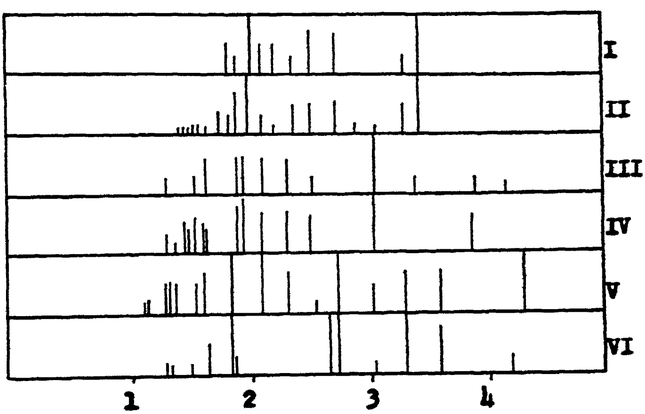

Fig. 2. The d-distances from x-ray diffraction data for the following: I. Precipitated calcium carbonate, needles; II. Argonite, A.S.T.M. cards; III. Precipitated calcium carbonate, rhombs; IV. Calcite, A.S.T.M. cards; V. Vaterite, A.S.T.M. cards; VI. Precipitated calcium carbonate, flocculent.

2. Time of aging in the mother liquid. Aging in each case caused a growth of the crystals, but in no case was there any distinct change in form upon aging. Even vaterite spherulites, contrary to expectations based upon earlier published reports, were found to remain as spherulites rather than reverting to calcite rhombs. Aging of the alcohol-formed

floc did result in the appearance of a few rhombs, but the predominant tendency was definitely to retain a shape indicative of the same crystal form. (As stated above, a total elapsed time of nearly five minutes was required to complete the mounting procedure; the observed effects of longer aging periods indicate that likely no significant changes of crystal form could have occurred during that five minute period.) Thus all crystal forms appear to be quite stable in contact with the mother liquid.

3. pH at time of precipitation. The pH of the precipitation medium at the time of precipitation was adjusted to several values ranging from 7.4 to 11. The crystal form of the precipitated calcium carbonate was independent of the pH.

4. Temperature of formation from aqueous medium. At temperatures ranging from 8° C. to 50° C., the calcite rhomb is the dominant form, with lesser quantities of spherulitic vaterite appearing. The relative amount of vaterite was found to decrease as the temperature was increased, with no vaterite appearing above 50° C. At 55° C.

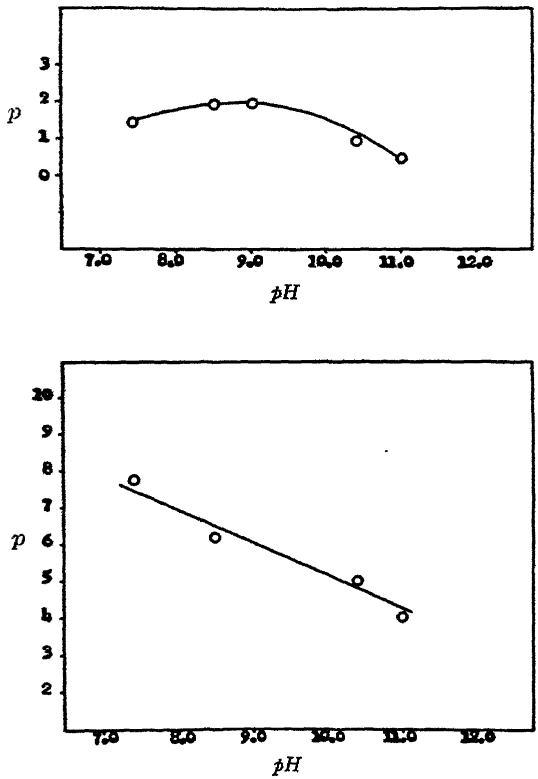

Fig. 3. Particle size as function of pH (top 5 min. size; bottom 30 min. size)

aragonite began to appear with calcite, either as bunches of strings (vigorous shaking) or as "cauliflowers" (slow mixing). Pure aragonite appeared at temperatures from 57° C. to 73° C., with a little calcite also appearing at still higher temperatures. As stated above, the role of temperature in determining the crystal form has been studied extensively elsewhere; these results are in essential agreement with previously published results with the additional identification of the flocculent material as vaterite.

Particle Size. Each particle size determination was made by measuring all the particles in the center region of the mounted specimen, covering about 15 openings of the 200-mesh supporting grid. About 250 to 300 particles were measured in each determination. Most measurements were made visually with the aid of graduations on the fluorescent viewing screen, although micrographs were taken periodically to check the measurements. The calibration of the electron microscope was made by observation of uniformly-sized polystyrene latex spheres supplied by courtesy of the Dow Chemical Company. The length of the longest side was taken as the size of the calcite rhomb, and the diameter as that of the spherulitic vaterite. The particle size was studied as a function of the pH of formation, of the time of aging in the mother liquid, and of the temperature of formation.

1. pH of formation. These results are shown graphically in figure 3. Because the pH would be expected to influence the solubility of calcium carbonate through the carbonate-bicarbonate equilibrium, and because the solubility would be expected to influence the rate of precipitation through the von Weimarn concepts, it should be expected that the particle size would be a function of the pH at the time of precipitation. It is noted that the five minute size vs. pH curve differs from that of the thirty minute one in that the former has a definite maximum within the pH range studied; this may be accounted for by the fact that the von Weimarn rate of precipitation is slower for the more soluble precipitates so that some of the precipitates measured rapidly after formation had not had time to reach a size which could be considered normal for those particular conditions. Therefore the thirty minute sizes may be taken as of more significance in determining the influence of pH upon particle size.

It is possible to calculate the influence of pH upon the solubility of the calcium carbonate, and then from the experimental data to observe the relationship between solubility and particle size. The solubility calculation may be summarized as follows.

Set up simultaneous equations—

$$6\times10^{-11}=\frac{(H^+)(CO_3^=)}{(HCO_3^-)}$$

$$3\times10^{-7}=\frac{(H^+)(HCO_3^-)}{(H_2CO_3)}$$

$$9\times10^{-9}=(Ca^{++})(CO_3^=)$$

$$1\times10^{-14}=(H^+)(OH^-)$$

$$(H^+)+2x10^{-1}+\frac{(Ca^{++})}{2}=(OH^-)+\frac{(CO_3^-)}{2}+2x10^{-3}+(HCO_3^-);$$

this series of five equations with six unknowns makes possible the determination of one of the unknowns, (Ca^{++}), which is in reality the molar solubility of calcium carbonate, in terms of another, the (H^+); the results are as follows along with a tabulation of the thirty minute size data from figure 3:

pH	molar solubility	log mol. soly	size
7	7.6×10^{-5}	—4.12	7.9
8	7.6×10^{-6}	—5.12	7.0
9	7.7×10^{-7}	—6.11	6.0
10	9.7×10^{-8}	—7.01	5.2
11	3.1×10^{-8}	—7.51	4.2

It is apparent that the size of crystal is an inverse function of the log of the solubility,

$$\text{size}=\frac{k}{\text{log molar soly}},$$

in which the proportionality constant, k, is about —35 for this

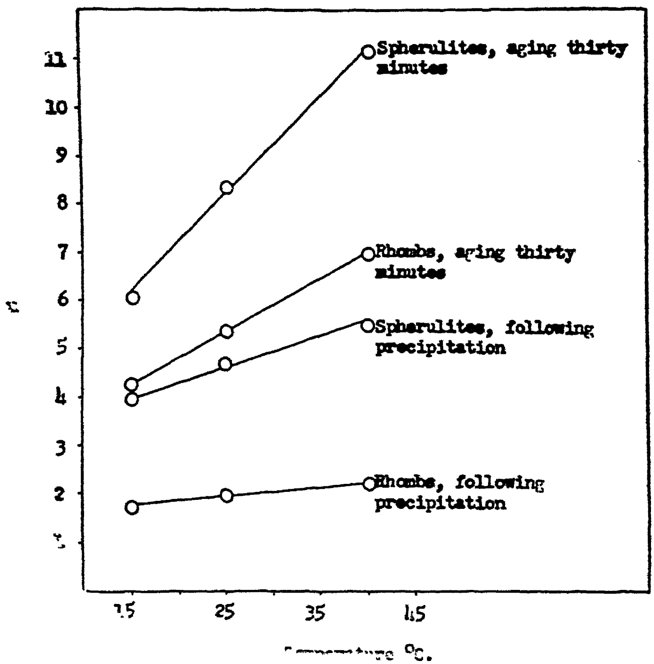

Fig. 4. Particle size as function of time of aging in mother liquid.

particular series. The von Weimarn concept states that the rate of precipitation is a function inversely of the solubility, rate $=\frac{Q}{S}$, Now these data show further that the size of crystal precipitated is an inverse function of the log of the solubility. It might seem that such a relationship could be determined with any one of a number of precipitates but such is seldom possible because a change in solubility is often accompanied by some sort of change in crystal form or at least in degree of perfection of the crystals. In the case of calcium carbonate, the form and shape and degree of perfection have just been shown to be independent of pH.

2. Time of aging in mother liquid. In every case studied, the particle size increased during aging in the mother liquid. A thirty minute period, in general caused an increase of 100% to 200% for the rhombs and an increase of 50% to 100% for the spherulites, each based upon the five minute size as reference, figure 4. This tendency is to be expected on the basis of Ostwald ripening concepts, a phenomenon often encountered, even though it is not as common as formerly thought.

3. Temperature of formation. The particle size of precipitated calcium carbonate, whether calcite rhombs or vaterite spherulites, was found to increase with rising temperature of precipitation. This appears at first to be contrary to expectations, because Seidell's solubility tables indicate a very definite decrease in solubility with rising temperature. An explanation may be based upon a consideration of the influence of temperature on the ionization constants of water and of carbonic acid. Qualitatively, the ionization of water increases as the temperature rises, thus increasing the H^+ ion concentration to complex more carbonate ions, in turn tending to offset any inherent solubility decrease. Calculations indicated that the increased complexing of carbonate ions is more than enough to offset any nominal decrease in solubility and thus is adequate to account for the observed phenomenon. However, the quantitative influence of temperature upon solubility product of calcium carbonate and upon ionization constants of carbonic acid do not appear well enough established to justify any more than a qualitative suggested explanation for the increase in particle size as the temperature is increased.

Summary

The precipitation of calcium carbonate has been studied with the aid of the electron microscope and x-ray diffraction to ascertain the effects of various conditioning factors upon the crystal form and the particle size of precipitate. Factors studied are the medium from which precipitated, the time of aging in contact with the mother liquid, the pH at the time of precipitation and the temperature of formation.

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Substituted Quinolineacetic Acids[1, 3]

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It was of interest to prepare several substituted quinolineacetic derivatives since at the time this work was begun very few had been recorded in literature.

The ethyl esters of both 2- and 4-quinolineacetic acids have been prepared by Borsche and co-workers (1). These were synthesized from the quinolinepyruvic ester obtained by condensation of quinaldine and lepidine, respectively, with ethyl oxalate. 3-Carbostyrilacetic acid (7) has been obtained by ring closure of o-aldehydosuccinanilic acid. More recently, 2- and 4-quinolineacetic acid esters have been reported by Weiss and Hauser (8) who obtained them through the carbethoxylation of quinaldine and lepidine, respectively, using ethyl carbonate and potassium amide. Jones and co-workers (4) prepared the ethyl esters 3-, 6- and 8-quinolineacetic acid during a study of penicillin precursors. Ethyl 4-hydroxy-2-methyl-6-quinolineacetate (5) has been obtained from methyl acetoacetate and ethyl p-aminophenylacetate. The highly substituted 4-carboxy-2-(2-thienyl)-3-quinolineacetic acid (3) was obtained through the Pfitzinger reaction between isatin and β-(2-thenoyl)-propionic acid. 8-Quinolineacetic acid preparation from 8-acetylquinoline by the Willgerodt reaction has been reported in a patent (2).

This report deals with the preparation of substituted 6- and 8-quinolineacetic acids obtained through the condensation of ethyl ethoxalylacetate with ethyl esters of 4- and 2-aminophenylacetates and subsequent ring-closure in boiling phenyl ether. The use of p-aminophenylacetonitrile instead of ethyl p-aminophenylacetate gave the corresponding 2-carbethoxy-4-hydroxy-6-quinolineacetonitrile. Attempts at decarboxylation of IV did not yield 4-hydroxy-6-quinolineacetonitrile; only high wide-range melting substances were obtained which could not be purified to workable materials. Likewise, no identifiable materials could be isolated from the decarboxylation of III. Carbon dioxide was liberated freely in both instances.

Experimental

Ethyl 2-Carbethoxy-4-hydroxy-6-quinolineacetate (I).—A solution of 13.7 g. (0.076 mole) of ethyl p-aminophenylacetate and 15g. (0.08 mole) of ethyl ethoxalylacetate in 75 ml. of methylene chloride with a drop of dilute hydrochloric acid was refluxed under a condenser with

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[1] Abstracted from a thesis of N.J.K. submitted to the Faculty of the Graduate School in partial fulfillment of the requirements for the degree, Doctor of Philosophy, in the Department of Chemistry, Indiana University (July, 1947).

[2] The Wm. S. Merrell Company Fellow, 1946-1947.

[3] Contribution number 504 from the Chemistry Laboratory of Indiana University.

trap for a heavier than water liquid until no more water was collected. After removal of the solvent, the oily residue was dissolved in warm diphenyl ether and added dropwise over a period of twenty minutes to 100 ml. of boiling diphenyl ether. After no further quantity of ethyl alcohol distilled, the reaction mixture was allowed to cool, the solid removed by filtration, washed with diphenyl ether and petroleum ether then recrystallized from 70-80% ethyl alcohol. The yield of light tan colored solid was 12.1 g. (53%), m.p. 187-188.5°.

Anal. Calc'd. for $C_{16}H_{17}NO_5$: N, 4.61%. Found: N, 4.87%.

2-Carbethoxy-4-hydroxy-6-quinolineacetonitrile (II).—This substance was prepared from p-aminophenylacetonitrile according to the method described above. Recrystallized from methyl cellosolve, the substance melted at 220-227°; the yield was 53%.

Anal. Calc'd for $C_{14}H_{12}N_2O_3$: N, 10.93%. Found: N, 11.25%

2-Carboxy-4-hydroxy-8-quinolineacetic acid (III).—Ethyl o-aminophenylacetate hydrochloride (21.6 g., 0.1 mole) was condensed with 23.3 g. of ethyl sodium ethoxalylacetate in absolute ethyl alcohol according to the method described by Lisk and Stacy (6). Ring closure of the crude azomethine was accomplished in 800 ml. of boiling diphenyl ether. After the reaction mixture cooled, no solid could be induced to separate so the diphenyl ether was heated with 300 ml. of 5% sodium hydroxide solution under a reflux condenser while the mixture was stirred mechanically. After separating the aqueous layer and neutralization with concentrated hydrochloric acid, the yield of the dicarboxylic acid was 17.6 g. (71%), m.p. 236-238°. Attempts at further purification did not raise the melting point.

Anal. Calc'd for $C_{12}H_9NO_5$: N, 5.67%. Found: N, 5.57%.

2-Carboxy-4-hydroxy-6-quinolineacetonitrile (IV).—Five grams (0.02 mole) of II was refluxed for 20 minutes with 25 ml. of 5% aqueous sodium hydroxide, the hot solution filtered and added dropwise to cold hydrochloric acid. The yield of light tan colored solid was 4.1 g. (92%), m.p. 256-258°. After recrystallization from glacial acetic acid, the substance melted at 257.5-258°.

Anal. Calc'd. for $C_{12}H_8N_2O_3$: N, 12.28%. Found: N, 11.90%.

Upon attempted recrystallization of II by boiling 40 g. of the substance in 300 ml. of glacial until solution occurred (30-40 minutes) then the solution cooled, a solid crystallized in almost theoretical yield which proved to be identical with IV. Apparently transesterification had occurred during the heating process.

2-Carbethoxy-4-chloro-6-quinolineacetonitrile (V).—A solution of 7.7 g. (0.05 mole) of phosphoryl trichloride in 50 ml. of dry benzene was added to 6.4 g. (0.025 mole) of II contained in a 200 ml. flask. The mixture was warmed and shaken at 60° for twenty minutes, then the reaction mixture was hydrolysed in ice-water and the semisolid mass isolated, neutralized and recrystalized from dioxane. The yield of long

fine needles of slightly tan solid was 1.0 g. (18%) which melted at 205.5-206°.

Anal. Calc'd for $C_{14}H_{11}ClN_2O_2$: N, 10.20%. Found: N, 10.60%.

Ethyl 2-Carbethoxy-4-hydroxy-6-quinoline-a-cyanoacetate (VI).—A mixture of 0.2 mole of sodium ethoxide and 25.6 g. (0.1 mole) of 2-carbethoxy-4-hydroxy-6-quinolineacetoniorile in 200 ml. of purified ethyl carbonate was heated at 55-60° in a 500-ml. three-necked flask equipped with a stirrer and a 24-inch column packed with glass helices. The pressure was maintained at about 100 mm. while the reaction mixture was heated during a twelve hour period. A portion of the ethyl carbonate was removed by distillation, the solid collected by filtration then triturated with dilute acetic acid. The yield of the crude substance was 30 g., m.p. 155-165°. After recrystallization from ethyl acetate, the substance melted at 168-170°, yield 13 g. (45%).

Anal. Calc'd for $C_{17}H_{16}N_2O_5$: N, 8.53%. Found, N, 8.38%.

2-Carboxy-4-hydroxy-6-quinolineacetic acid (VII).—A solution of 49.2 g. (0.19 mole) of II in 300 ml. of 7-8% sodium hydroxide was refluxed until tests (8 hours) indicated that no more ammonia was being evolved. After treatment of the hot solution with Norite and filtration, it was acidified with concentrated hydrochloric acid. The yield of VII was 98%, the substance melted at 286-288° with decomposition. VII may be recrystallized from methyl cellosolve.

Anal. Calc'd. for $C_{12}H_9NO_5$: N, 5.6%. Found: N, 5.42%.

Saponification of I and IV gave substances which were identical with VII.

2-Carboxy-4-chloro-6-quinolineacetic acid (VIII).—A suspension of 12.4 g. (0.05 mole) of VII was mixed with 100 ml. of benzene containing 30.6 g. (0.2 mole) of phosphoryl trichloride was kept at 60° for four hours, then the solid triturated with water and dissolved 125 ml. of hot ethylene glycol. After filtration, 25 ml. of n-butyl alcohol was added and the substance allowed to crystallize. The yield was 7 g. (53%) of tan-colored crystals, m.p. 230-232°. Recrystallization did not change the melting point.

Anal. Calc'd for $C_{12}H_8ClNO_4$: N, 5.27%. Found: N, 4.94%.

2-Carboxy-6-quinolineacetic acid (IX).—Seven grams (0.026 mole) of VIII was hydrogenated in ethyl alcohol at 40 p.s.i. using palladium—charcoal catalyst. After six hours, the solid was remoevd by filtration, then triturated with 5% sodium hydroxide solution to dissolve the crude IX. After filtration of the solution, it was acidified with dilute hydrochloric acid. The yield of crude IX was 4.2 g. (67%). After recrystallization from acetic acid, the substance melted at 270-272°.

Anal. Calc'd for $C_{12}H_9O_4N$: N, 6.06%. Found: N, 5.88%.

2-Carboxy-4-Methoxy-6-quinolineacetic acid (X).—Two grams of VIII was refluxed for one hour with 25 ml. of absolute methyl alcohol

in which one gram of sodium had been dissolved. After cooling, 20 ml. of water was added and the solution added slowly to cold dilute nitric acid. The crude X (m.p. 272-275°) was recrystallized from methyl cellosolve as white needles. The yield was 1.2 g. (61%) and the purified X melted at 272.5-274°.

Anal. Calc'd. for $C_{13}H_{11}NO_5$: N, 5.36%. Found: N, 5.44%.

2-Carboxy-4-Chloro-8-quinolineacetic acid (XI).—This substance was prepared from 4 g. of III by the same procedure as was used in the case of VIII, except that the benzene and phosphoryl trichloride were removed in vacuum. The yield was 4 g. (93%). The substance melted with decomposition at 252-253°.

Anal. Calc'd. for $C_{12}H_8ClNO_4$: N, 5.27%. Found: N, 5.22%.

2-Carboxy-4-hydroxy-5 (and 7)-quinolineacetic acid (XII).—This substance was prepared from 36 g. (0.168 mole) ethyl m-aminophenylacetate hydrochloride and 44 g. (0.19 mole) of ethyl sodium ethoxalylacetate exactly as in the case of III. After treatment of the crude XII with Norite in dilute sodium hydroxide it was obtained on acidification with hydrochloric acid as a light cream colored solid which melted with decomposition at 220-250°. The yield was 13 g. (31%).

Anal. Calc'd for $C_{12}H_9NO_5$: N, 5.67%. Found: N, 5.78%.

Summary

The Conrad-Limpach type of reaction was used to prepare ethyl 2-carbethoxy-4-hydroxy-6-quinolineacetate and ethyl 2-carbethoxy-4-hydroxy-6-quinolineacetonitrile from ethyl ethoxalylacetate and ethyl p-aminophenylacetate and p-aminophenylacetonitrile, respectively. 2-carbethoxy-4-hydroxy-6-quinolineacetonitrile was saponified partially to give 2-carboxy-4-hydroxy-6-quinolineacetonitrile or could be saponified completely to the dicarboxylic acid depending upon the conditions. Carbethoxylation of 2-carbethoxy-4-hydroxy-6-quinoleacetonitrile in ethyl carbonate solution by sodium ethoxide gave ethyl 2-carbethoxy-4-hydroxy-6-quinoline-α-cyanoacetate. 2-Carboxy-4-hydroxy-8-quinolineacetic acid was obtained by the saponification of the ester obtained by the condensation of ethyl ethoxalylacetate with ethyl o-aminophenylacetate.

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Substituted Benzylquinolines[1, 2]

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The purpose of the preparation of 6-(p-bromobenzyl)-quinaldine and -lepidine was to study certain reactions involving the halogen atom in the benzyl group. Both 6-(p-bromobenzyl)-4-hydroxyquinaldine and 6-(p-bromobenzyl)-4-methylcarbostyril were prepared according to the method described previously (3) The hydroxy quinolines were converted readily to the coresponding chloro compounds by treatment with phosphoryl trichloride but unexpected difficulties were encounterd in removal of the chlorine atom by catalytic reduction. In the catalytic reduction of 6-(p-bromobenzyl)-4-chloroquinaldine under the usual conditions, both the chlorine and the bromine atoms were removed to give 6-benzylquinaldine. Under less drastic conditions. The substance was recovered unchanged.

Catalytic reduction of 6-(p-bromobenzyl)-2-chlorolepidine (V) gave two substances, neither of which was the expected product. One substance was an ether soluble material containing no halogen, therefore was 6-benzyllepidine. The other product was insoluble in ether and melted at a high temperature over a considerable range. From this was isolated a substance which contained the correct percentage of halogen for 6-p-bromobenzyllepidine but the melting point, 240-42°, is not compatible with the structure of the substance. A molecular weight determination gave a value of 557 which is almost twice that for 6-p-bromobenzyllepidine. It would appear that bimolecular reduction had occurred during removal of the chlorine atom. Such bimolecular reductions have been reported by Busch and Weber (1). The substance contained bromine therefore it is in all probability 2, 2′-bis-6-(p-bromobenzyl)-lepidine. No attempt was made at structure proof. Catalytic reduction of V under less drastic conditions gave further mixtures. The ether soluble portion of the reduction products contained as much as 11-13% halogen and the ether insoluble portion could not be purified to yield a material of short melting point range.

Experimental

4-p-Bromobenzylaniline (I), 6-(p-bromobenzyl)-4-methylcarbostyril (II) and 6-(p-bromobenzyl)-4-hydroxyquinaldine (III) were prepared according to the method described previously (2, 3).

6-(p-Bromobenzyl)-4-chloroquinaldine (IV).—Fifty-two grams (0.158 mole) of III was mixed with 150 g. (0.97 mole) of phosphoryl

[1] Taken from a thesis presented by Harry D. Williams in partial fulfillment of the requirements for the M. A. degree, August 1947.

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trichloride and the substances heated in a boiling water bath for two hours. The contents of the flask were then poured onto 200-250 g. of cracked ice and the solution neutralized with concentrated ammonia water. After removal of the solid, it was recrystallized from 100 ml. of 80% ethyl alcohol. IV was obtained as fine white needles. The yield was 35 g. (71%); the substance melted at 90-93°. The melting point could not be raised above 95-96° by three recrystallizations from ethyl alcohol.

Anal. Calc'd for $C_{17}H_{13}BrClN$: BrCl, 33.29%. Found: BrCl, 33.16%.

6-(p-Bromobenzyl)-2-chlorolepidine (V).—Phosphoryl trichloride (50 g., 0.325 mole) was added to 20 g. (0.061 mole) of II and the mixture heated in a boiling water bath until all of the solid was dissolved, then the solution poured onto 200-250 g. of ice. After standing for two hours, the solid was removed by filtration and washed until the acid was removed. The yield of tan-colored solid was 20 g. (94%), m.p. 103-106°. The substance melted at 107.5-108.5° after recrystallization from ethyl alcohol.

Anal. Calc'd for $C_{17}H_{13}BrClN$: BrCl, 33.29%. Found: BrCl, 33.05%.

Reduction of 6-(p-Bromobenzyl)-4-chloroquinaldine (IV).—Three grams of palladium-charcoal catalyst (4) was added to a solution of 9 g. (0.023 mole) of IV dissolved in 200 ml. of glacial acetic acid containing 8 g. of anhydrous sodium acetate. The hydrogenation was carried out at 65-70°' and at 40 p.s.i. pressure. The hydrogenation was continued until there was no further drop in pressure (4-5 hours). After removal of the catalyst by filtration, most of the acetic acid was removed by vacuum distillation, ice was added and then the residue was made slightly alkaline with sodium hydroxide. The yield of dry crude solid was 5 g. (92%), which melted at 78-81°. After two recrystallizations from 30-40% ethyl alcohol, the substance was obtained as slightly yellow needles, which melted at 81-82°.

Neither the crude nor the purified substance gave slightest test for halogen, therefore the reduction product must have been 6-benzylquinaldine.

Anal. Calc'd for $C_{17}H_{15}N$: N, 6.01%. Found: N, 6.05%.

Reduction of 6-(p-bromobenzyl)-2-chlorolepidine (V).—Thirteen grams (0.038 mole) of V was reduced catalytically in exactly the same procedure as for the reduction of IV. After removal of the acetic acid and neutralization with sodium hydroxide, there was obtained an oil and a solid. The oil was soluble in ether and the solid (VI) was not appreciably soluble in the latter solvent. After drying and distillation of the ether, the residue distilled at 215-222° at 8 mm. pressure; the yield was 4 g. The oil gave a positive test for halogen. After standing for several days, large crystals appeared; these were removed, washed with a small amount of cold ether. The crystals weighed 1.2 g. After recrystallizations from dilute ethyl alcohol, the substance melted at 63.5-

65°. The test for halogen was negative; it must be presumed the substance is 6-benzyllepidine.

Recrystallization of the solid VI (5.8 g.) several times finally gave 0.8 g. of a white crystalline substance which melted at 240-242°.

Anal. Calc'd for $C_{34}H_{28}N_2Br_2$: Br, 25.7%; Mol. Wt., 622. Found: Br, 25.42%; Mol. Wt., 557.

Methyl 4, 4'-Methylenebis-(β-anilinoanilino) crotonate (VII).—A solution of 99 g. (0.5 mole) of 4, 4'-diaminodiphenylmethane (2) and 147 g. (1.27 moles) of methyl acetoacetate in 300 ml. of methylene chloride containing one drop of dilute hydrochloric acid was refluxed with a trap for liquids heavier than water attached. After the theoretical amount of water had separated, the methylene chloride was removed by distillation and the residual liquid mass poured into 200 ml. of cold ligroin. The solid was removed by filtration after it had been allowed to stand in a refrigerator over night. The yield of crude VII was 190 g. (96.4%); the substance melted at 93-97°. Purification of a ten-gram portion through recrystallization from a benzene-ligroin solution (1 to 20 by volume) gave white silky needles which melted at 101.5-102°.

Anal. Calc'd for $C_{23}H_{26}N_2O_4$: N, 7.10%. Found: N, 7.03%.

6,6'-Methylenebis-(4-hydroxyquinaldine) (VIII).—A solution of 50 g. (0.127 mole) of VII in 70 ml. of di-n-butyl phthalate at 70° was added slowly by means of a separatory funnel to vigorously stirred butyl phthalate which was maintained at 260-270°. The heating was continued, after VII was added, until no further distillation of methyl alcohol occurred. After the solution cooled, the solid was removed by filtration and washed, successively with a ligroin-butyl phthalate solution (1:1), then with ligroin and finally the solid was refluxed with benzene. The yield of crude dark tan colored VIII was 40 g. (95%) and it melted at 410-415° with decomposition. No solvent could be found for purification of the substance by recrystallization but it was soluble in a large excess of 3 N hydrochloric acid crystallized partially from the cold solution. Addition of alkili to the acid filtrate precipitated any VIII which remained in the hydrochloric acid.

Anal. Calc'd for $C_{21}H_{18}N_2O_2$: N, 8.48%. Found: N, 6.59%.

6,6'-Methylenebis-(4-chloroquinaldine) (IX).—A mixture of 50 g. (0.325 mole) of phosphoryl trichloride and 30 g. (0.09 mole) of VIII was heated for four hours in a boiling water bath. After the mixture had been poured onto about 200 g. of ice then the solution neutralized with concentrated ammonia water, the aqueous layer was decanted from the tarry semi-solid mass. The dark colored solid was dissolved in boiling ethyl alcohol, filtered and cooled to crystallize the crude IX as dark tan needles. The yield was 16 g. (48%). After three recrystallizations from ethyl alcohol, the substance melted at 159-160°.

Anal. Calc'd for $C_{21}H_{16}Cl_2N_2$: Cl, 19.32%. Found: Cl. 19.13%.

6,6'-Methylenebis-(4-methoxyquinaldine).—Twenty-four grams (0.065 mole) of IX was added to a solution of 23 g. (1 mole) of sodium in 360

ml. of absolute methanol, then the mixture heated to reflux temperature and benzene added while the methyl alcohol was removed by distillation. The mixture was heated for 40-50 minutes, then poured into one liter of water. The liquid was filtered to remove the solid, then the benzene layer separated and distilled. The solid residues were combined and recrystallized from 100 ml. of ethyl alcohol. The yield was 22 g. (98%). After recrystallization from alcohol and from dioxane, the substance melted at 222.5-224°.

Anal. Calc'd for $C_{23}H_{22}N_2O_2$: N, 7.82%. Found: N, 7.60%.

Summary

The preparation of 6-(p-bromobenzyl)-2-chlorolepidine and 6-(p-bromobenzyl)-4-chloroquinaldine from the corresponding 2-, and 4-hydroxy compounds has been reported. Catalytic reduction of 6-(p-bromobenzyl)-4-chloroquinaldine over palladium on charcoal gave 6-benzylquinaldine. Reduction of 6-(p-bromobenzyl)-2-chlorolepidine by the same method gave 6-benzyllepidine and a substance believed to be 2,2'-bis-6-(p-bromobenzyl)-lepidine.

Condensation of 4,4'-diaminodiphenylmethane with methyl acetoacetate according to the modified Conrad-Limpach method gave 6,6'-methylenebis-4-hydroxyquinaldine. This substance was converted to the corresponding 4-chloro compound using phosphoryl trichloride. Treatment of 6,6'-methylenebis-4-chloroquinaldine with sodium methoxide in boiling benzene gave the corresponding 4-methoxy compound.

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Isoquinoline in Chemical Microscopy: A Reagent for Zinc and Cadmium

HAROLD F. SCHAEFFER, Valparaiso University

As pointed out by Spakowski and Freiser (1), when a solution containing isoquinoline and a thiocyanate is added to solutions of certain divalent cations, precipitates corresponding to the formula $M(C_9H_7N)_2(CNS)_2$ are formed. Although these two workers applied the reagent in the quantitative precipitation of zinc and copper, they did not investigate its possibilities in the field of chemical microscopy. We have now found that the isoquinoline-thiocyanate reagent can be employed in the microchemical detection of zinc or cadmium ions because the resulting metallo-organic compounds separate in the form of microscopic crystals.

Since isoquinoline is only slightly soluble in water, it is used in the form of the hydrochloride. For use in chemical microscopy the reagent is prepared by dissolving 13 g. isoquinoline in 75 ml. of N-hydrochloric acid, adding 19 g. of ammonium thiocyanate, and diluting to one liter with distilled water. Such a solution will contain approximately 0.25 mole of ammonium thiocyanate and 0.1 mole of isoquinoline hydrochloride per liter. The isoquinoline obtained by recrystallizing E. K. Co. *practical* grade has been found satisfactory for this purpose.

In performing a test a small drop of reagent is allowed to flow into

Figure 1. Crystals formed by the presence of zinc ions. (Scale for Fig. 1 should be labeled o.4 mm.)

Figure 2. Crystals formed by the presence of cadmium ions.

a small drop of test solution on a slide. Characteristic crystals (Fig. 1) are formed with dilute solutions of various zinc salts, including the chloride, nitrate, acetate, sulfate, etc. With zinc acetate, for example, good tests have been obtained on solutions containing less than one part zinc in 10,000. This makes it possible to detect one gamma in a microdrop of sample. The composition of the crystals is represented by the formula $Zn(C_9H_7N)_2(CNS)_2$.

When treated with the same isoquinoline-thiocyanate reagent, cadmium yields characteristic crystals somewhat smaller than those formed by zinc salts (Fig. 2). The test appears less sensitive for cadmium, although good tests are obtained on solutions containing 1 part cadmium in one or two thousand parts of solution. The complex compounds formed by both zinc and cadmium yield anisotropic crystals. Common cations which may interfere with the tests include silver, mercuric, nickel, cobalt, cupric, and trivalent bismuth and antimony. In the presence of ferric ion the test for cadmium or zinc may be obscured by the formation of practically opaque cubic crystals and a red solution. However, if the iron is present in very small amounts (1 part in 10,000) the tests will not be obscured.

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Synthesis of 7-Nitrofluorenone-2-Carboxylic Acid[1]

SISTER MARY ROSE STOCKTON, Marian College, Indianapolis

The synthesis of 7-nitrofluorenone-2-carboxylic acid was first attempted by nitrating fluorenone-2-carboxylic acid. A yellow product resulted which melted above 300° C. In order to prove the structure of this product, it was decided to decarboxylate it and identify the resulting nitrofluorenone by comparing its properties with those nitrofluorenones described in the literature. All attempts at decarboxylation ended in failure. The yellow product obtained at the direct nitration of fluorenone-2-carboxylic acid later proved to be a complex of a mono-nitro- and a dinitro-fluorenone-2-carboxylic acid.

It was then decided to synthesize 7-nitrofluorenone-2-carboxylic acid from fluorene by a series of reactions which would leave no doubt as to its structure.

Fluorene was first converted to 2-nitrofluorene by the method given in *Organic Syntheses* (6) using concentrated nitric acid with glacial acetic acid as a solvent. The 2-nitrofluorene was then added to a mixture of equal volumes of glacial acetic acid and fuming nitric acid forming 2,7-dinitrofluorene (4). The literature gives three different melting points for 2,7-dinitrofluorene: Morgan and Thomason (5) give the melting point as vigorous decomposition at 269° C; Anantakrishnan and Hughes (1) state that their compound melted with vigorous decomposition at 295-300° C; Courtot (2) obtained a melting point of 334° C after he had recrystallized his compound from nitrobenzene.

Each time we prepared 2,7-dinitrofluorene our product consistently melted at 269° C in agreement with the melting point given by Morgan and Thomason. Repeated recrystallizations from acetic anhydride of a small sample, however, gave long, almost colorless, glistening needles melting sharply at 299° C. This melting point agrees with that given by Anantakrishnan and Hughes (1).

Crude 2,7-dinitrofluorene was oxidized to 2,7-dinitrofluorenone with sodium dichromate, using 3:1 mixture of glacial acetic acid and acetic anhydride as a solvent. The product melted over a range 240-270° C which was not in accordance with the melting point given by Anantakrishnan and Hughes, 292° C (1). By fractional extraction the supposed 2,7-dinitrofluorenone was separated into almost equal parts of 2,5-dinitrofluorenone melting at 239° C and 2,7-dinitrofluorenone melting at 293° C. When, however, the crude 2,7-dinitrofluorenone was completely dissolved in glacial acetic acid, the crystalline product which precipitated on cooling melted at 268° C. From this it is evident that the 2,5- and 2,7-dinitro-isomers can best be separated by fractional extraction.

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[1] This research was done at the University of Cincinnati under the direction of Dr. Francis E. Ray, now Director of Research at the Cancer Research Laboratory, University of Florida, Gainesville, Florida.

The reduction of the pure 2,7-dinitrofluorenone to 2-amino-7-nitrofluorenone with ammonium sulfide resulted after two recrystallizations from monochlorobenzene in beautiful glistening black needles which melted at 281-282° C. Eckert and Langecker (3) report a melting point of 279° C for 2-amino-7-nitrofluorenone.

2-Amino-7-nitrofluorenone was converted to the nitrile by the Sandmeyer reaction. It was difficult to extract the 2-cyano-7-nitrofluorenone from the reaction mixture. The final sublimation product was orange needles melting at 245-247° C. A nitrogen analysis gave 11.21% whereas the calculated nitrogen content for the compound is 11.20%.

2-Cyano-7-nitrofluorenone was refluxed with a solution of five percent potassium hydroxide in which the nitrile gradually dissolved, giving a red solution. The evolution of ammonia showed that hydrolysis was taking place. The 7-nitrofluorenone-2-carboxylic acid was precipitated from the alkaline solution with 1:1 hydrochloric acid and on sublimation gave an orange product melting at 210-213° C.

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ENTOMOLOGY

Chairman: G. GOULD, Purdue University

J. A. Clark, State Entomologist's Office, was elected chairman for 1951.

ABSTRACTS

The use of insects in designs of old buttons. GEORGE E. GOULD, Purdue University.—The use of insects as the motif on buttons was popular with designers of 50 to 100 years ago, as the author has collected over 500 different designs. Of the insect orders used the butterflies and moths have been the most popular, followed by the beetles, the bees and the flies, while the grasshoppers, the bugs and the various groups of lice rarely are seen. Among the more unusual buttons are those where actual insect specimens have been used, such as the tropical, metallic green Chrysomelid beetle, *Polyschalca punctatissima* (Wolf), and the habitat buttons where specimens were mounted under glass with moss, seeds and other plant material to simulate natural environments. Observed in these habitat buttons which were made in France around 1790, where the cabbage butterfly, the asparagus beetle, various small June beetles and the Spanish fly (blister beetle).

White Grub control in strawberries. G. EDW. MARSHALL, Purdue University.—Results from recent field research will completely change our recommendations with respect to new strawberry plantings. A study of soil insecticides applied to one hundred twentieth acre plots has made this possible. Heretofore growers have been advised to plant berries in new ground. To do this and in order to prevent damage from white grubs the procedure has been as follows; plow up the sod in August, grow a row crop such as corn or soy beans the next season and set to berries the following season. Now it is possible to treat the sod with BHC in April, plow up the sod the same day, work it down as soon as possible and set to berries the following day. Ground prepared in this manner in 1949 produced a first crop of Aromas in 1950 at the rate of 372 to 375 quart crates per acre even though the white grub population of this pasture land had been seven white grub larvae per square yard at the time of plowing.

The Bombidae of Indiana[1]

LELAND CHANDLER, Purdue University

Introduction

The insects of the family Bombidae are commonly called bumblebees. The family is made up of two genera, the genus *Bombus*, which includes the true bumblebee; and, the genus *Psithyrus*, which includes the inquiline bumblebees.

The bumblebees are characterized by being large hairy bees, the color of the pile being some combination of black and yellow, ferruginous, or rufous; the hind tibiae of the queens and workers of *Bombus* being dilated, with a fringe of stiff hairs on the lateral edges forming corbiculae or pollen-baskets; possessing apical tibial spurs; the marginal cell being pointed and as long as the three submarginal (cubital) cells united, extending far beyond the apex of the third submarginal cell; having the first submarginal cell nearly divided by a hair-like vein or nervure; and having the stigma poorly developed. There are three castes, queens, workers and males, in the genus *Bombus;* only females and males in the genus *Psithyrus.*

This paper lists fifteen species and three varieties of Bombidae as occurring within the state of which ten have been previously recorded. Thomas Say in his original description of *Bombus ternarius* in 1835 noted "Inhabits Indiana". Franklin (3) expressed the doubt that this species occurs in Indiana and listed eight other species of Bombus and one species of *Psithyrus.*

The collection of bumblebees belonging to the Entomology Department of Purdue University contains many determined specimens of nine Indiana species. The determinations were made by Dr. Henry J. Franklin, Mr. F. W. L. Sladen, Dr. Theodore Frison and Dr. Herbert E. Milliron. The Purdue University student collection was also studied, as were the private collections of Dr. B. E. Montgomery of the Purdue Entomology Department, Mr. William Kowlek of Gary, Carol and Dale Snelling of West Lafayette, and the collection of the author. The writer wishes to express his sincere appreciation to Dr. Howard O. Deay for his many helpful suggestions in the preparation of this paper and for specimens that were contributed by him for this work. Also to Mr. Ray T. Everly, who contributed many specimens from a wide range within the state, especial acknowledgment is made. Other collectors who gave material to the author are Mr. John Kingsolver, Mr. John Payne, Mr. Richard Thomas, Mr. Richard Wilkie, and Mr. M. Curtis Wilson.

The county has been chosen as the collection unit. Whenever a species is recorded from the state for the first time, locality, date and

[1] This is part of a Master's Degree thesis submitted to Purdue University in partial fulfillment for the degree of Master of Science.

host plant will be listed. This data is necessarily omitted for the common species.

A complete description of the species and varieties can be found in Franklin (3) and Chandler (1). A summary of characters has been written by Plath (6) and Stevens (7), while Frison (4) and Milliron (5) have presented them in key form. Cresson (2) may be consulted in connection with the insect group under discussion.

Key for the Separation of Sexes and Genera of Indiana Bombidae

1 Antennae with twelve segments; six visible ventral abdominal segments; tarsal claws unequal; possessing stings . . queens and workers of *Bombus;* females of *Psithyrus* 2

1′ Antennae with thirteen segments; seven visible ventral abdominal segments; tarsal claws subequal; without stings ....males of *Bombus* and of *Psithyrus*

2(1) Outer surface of each hind tibia flattened or concave, bare, with a fringe of long hairs on the lateral margins forming a corbicula or pollen-basket.... ....*Bombus*

2′ Outer surface of each hind tibia convex, evently covered with short hairs; possessing no corbicula....... ....*Psithyrus*

3(1′) Outer surface of each hind tibia with short hairs irregularily distributed; face usually covered with yellow pile; volsellae and squamae of genitalia corneus (Fig. 2)......*Bombus*

3′ Outer surface of each hind tibia well covered with short hairs; face usually covered with black pile, never with an admixture of yellow; volsellae and squamae of genitalia membraneous (Fig. 1)........ ....*Psithyrus*

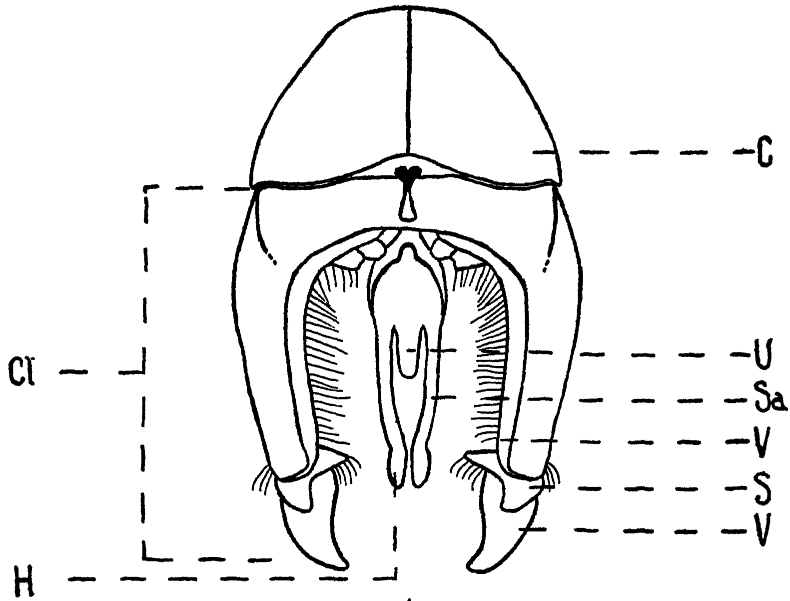
Genus *Bombus* Latreille

Latreille. Hist. Nat. Crust. and Insect, III: p. 385, 436. 1802.

This genus consists of the true bumblebees. There are three castes—queens, workers and males. Queens and workers may be easily separated from the *Psithyrus* females by the presence of corbiculae. No external characters have been found to distinguish the queens from the workers of most species of *Bombus* except by size, which is not a good criterion.

In order to readily distinguish the males of the two genera one must have considerable experience in working with them. For the most part *Bombus* males do not appear as shaggy as *Psithyrus* males and the color of the pile seems brighter since the black of the cuticle does not show through. *Bombus* males usually have considerable yellow pile on the face and *Psithyrus* males always have black pile with no admixture of yellow.

Twelve species and two varieties of *Bombus* are known to occur in Indiana.



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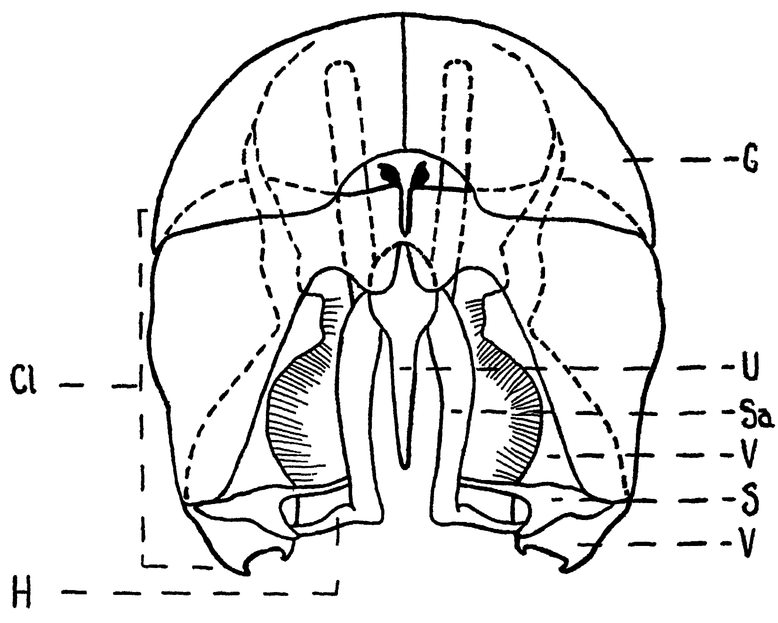

2.

FIG. 1. Dorsal view of male genitalia of *Psithyrus laboriosus* (Fabricius).
FIG. 2. Dorsal view of male genitalia of *Bombus americanorum* (Fabricius). C, cardo; Cl, clasper; H, head of sagitta; S. squama. Sa, sagitta; U: spatha; V, volsella.

Key for the Separation of Queens and Workers of Indiana *Bombus*

1	Dorsum of thorax yellow; the center of the disc may be bare and with a few black hairs bending over the bare spot	2
1′	An interalar black band or least black pile of irregular pattern between the wing bases which covers the scutellum in varying proportions	9
2(1)	Only the first abdominal tergite yellow, the remainder of abdomen black	*impatiens*
2′	The first abdominal tergite yellow or black, others with yellow, ferruginous or rufous pile	3
3(2′)	Lower portion of pleurae dark	*perplexus*
3′	Pleurae yellow throughout	4
4(3′)	First four abdominal tergites yellow	*fervidus* var. *dorsalis*
4′	Not all of first four abdominal tergites yellow	5
5(4′)	First abdominal tergite yellow; second abdominal tergite with a basal median ferruginous patch; workers sometimes with entire tergite ferruginous	*griseocollis*
5′	First abdominal tergite yellow; second abdominal tergite with some yellow pile	6
6(5′)	Second abdominal tergite with basal median yellow patch	*bimaculatus*
6′	Entire second abdominal tergite yellow	7
7(6′)	Occiput predominately black; malar space as wide at apex as long; yellow of second abdominal tergite notched; queens (15-21 mm.)	*affinis*
7′	Occiput usually yellow; malar space much longer than width at apex; yellow of second abdominal tergite entire: queens (13-17 mm.) and workers	8
8(7′)	Only first two abdominal tergites yellow	*vagans*
8′	First two abdominal tergites yellow; third tergite black; yellow on some of the apical tergites	*vagans* var. *helenae*
9(1′)	First four abdominal tergites yellow	10
9′	Not all of first four abdominal tergites yellow	11
10(9)	Occiput and face black; yellow of pleurae extending to or nearly to the bases of the legs; color lemon- or greenish-yellow	*fervidus*
10′	Occiput and face with whitish or yellowish pile; pleurae dark; color tawny yellow	*borealis*
11(9′)	Second and third abdominal tergites rufous; first and fourth tergites yellow; remainder of abdomen black	*ternarius*

11′	No abdominal tergite bearing rufous pile; fourth tergite black	12
12(11′)	Third abdominal tergite black.	13
12′	Third abdominal tergite yellow.	14
13(12)	First and second abdominal tergites yellow; remainder of abdomen black; ocelli placed well below the supraorbital line . . . . *fraternus*	
13′	First abdominal tergite yellow; second tergite ferruginous: workers . . . . *affinis*	
14(12′)	Occiput black; first abdominal tergite largely yellow; second and third tergites yellow; ocelli near supra-orbital line . . . . *americanorum*	
14′	Occiput with two yellow lines; first abdominal tergite largely black; second and third tergites yellow; ocelli below supra-orbital line . . . . *auricomus*	

Key for the Separation of Males of Indiana *Bombus*

1	Eyes large and bulging from the head; ocelli placed well below the supra-orbital line in narrow part of face.	2
1′	Eyes normal; ocelli on or near supra-orbital line	4
2(1)	First abdominal tergite yellow; second abdominal tergite with a basal median patch or ferruginous pile; remainder of abdomen black. . . . . *griseocollis*	
2′	No abdominal tergite bearing ferruginous pile.	3
3(2′)	First and second abdominal tergites yellow; remainder of abdomen black; malar space a mere line. . . . . *fraternus*	
3′	First abdominal tergite yellow or black; second and third abdominal tergites always yellow; malar space distinct. . . . . *auricomus*	
4(1′)	First abdominal tergite yellow; remainder of abdomen black . . . . *impatiens*	
4′	First abdominal tergite yellow; other tergites also bearing yellow	5
5(4′)	Second and third abdominal tergites rufous; sixth and seventh tergites black; remainder of abdomen yellow . . . . *ternarius*	
5′	No abdominal tergites bearing rufous pile	6
6(5′)	First abdominal tergite yellow; only basal median patch of yellow on second tergite; remainder of abdomen black . . . . *bimaculatus*	
6′	First abdominal tergite yellow; second tergite entirely yellow or ferruginous	7
7(6′)	Second abdominal tergite bearing admixture of yellow and ferruginous or entirely ferruginous pile. . . . . *affinis*	

7′ Second abdominal tergite never bearing other than yellow pile 8

8(7′) First two abdominal tergites yellow; remainder of abdomen black . . . . *vagans*

8′ Yellow of abdomen not confined to first two abdominal tergites 9

9(8′) Possessing a black interalar band 10

9′ Without a black interalar band 12

10(9) Occiput and face yellow; pleurae dark; first four abdominal tergites yellow . . . . . . *borealis*

10′ Occiput and face black; pleurae yellow or dark; first four abdominal tergites yellow 11

11(10′) Interalar band well defined; pleurae yellow; apical abdominal tergites always black; color lemon or greenish-yellow . . . . *fervidus*

11′ Black of interalar extending back so that scutellum is mixed with yellow and black; pleurae variable, usually dark; apical abdominal segment usually with ferruginous pile; color dull yellow. . . . . . . *americanorum*

12(9′) Occiput black; apical abdominal segment always black. . . . . *fervidus* var. *dorsalis*

12′ Occiput yellow; some apical abdominal tergites bearing yellow pile 13

13(12′) First three abdominal tergites yellow, possibly the entire abdomen yellow; apical abdominal segment with a fringe of light pile . . . . . . *perplexus*

13′ First two abdominal tergites yellow; third tergite black; some of the apical tergites bearing yellow pile . . . . *vagans* var. *helenae*

Genus *Psithyrus* Lepeletier

Lepeletier. Ann. Soc. Ent. France, I: p. 372. 1832.

This genus consists of the inquiline bumblebees of which there are only females and males.

The female *Psithyrus* invades the nest of a species of *Bombus* and disposes of the queen by stinging her to death. She then takes over the nest and lays her own eggs, destroying any *Bombus* eggs which might have been laid. It is said that *Bombus fervidus* will not tolerate the intrusion of *Psithyrus* and in some cases the inquiline female is attacked by workers of other species and the invasion is repulsed.

The species of *Psithyrus* have specific hosts, generally not more than two species of *Bombus* in a single locality; therefore, the range of any species of *Psithyrus* coincides with that of the hosts. This genus is inquilinous only in the nests of *Bombus*.

Key for the Separation of the Females of Indiana *Psithyrus*

1	Pleurae dark throughout or at least the lower portion dark .	2
1′	Pleurae entirely yellow.	3
2(1)	Occiput black; abdominal tergites with some yellow pile. . . . . *ashtoni*	
2′	Occiput yellow; abdomen entirely black . *variabilis*	
3(1′)	Mesonotum with some black pile; fourth and fifth abdominal tergites bearing yellow pile . . . . . . *insularis*	
3′	Mesonotum with little or no black pile; fourth abdominal tergite black	4
4(3′)	Abdomen usually entirely black; sometimes with touches of yellow pile on the sides of the third abdominal tergite . . . . *laboriosus*	
4′	Third abdominal tergite entirely covered with yellow pile; remainder of abdomen black *laboriosus* var. *citrinus*	

Key for the Separation of Males of Indiana *Psithyrus*

1	Pleurae yellow throughout	2
1′	Pleurae dark throughout or at least lower portion dark . .	4
2(1)	Mesonotum with black pile suggesting an interalar band; some abdominal tergites after third bearing yellow pile . . . . *insularis*	
2′	Mesonotum usually bare in center or with a slight admixture of black pile; no abdominal tergite after the third bearing other than black pile	3
3(2′)	First two abdominal tergites yellow; remainder of abdomen black . . . . *laboriosus*	
3′	First three abdominal tergites yellow; remainder of abdomen black . . . . *laboriosus* var. *citrinus*	
4(1′)	First abdominal tergite entirely yellow; third and fifth antennal segments subequal . . *ashtoni*	
4′	First abdominal tergite mostly black, occasionally yellow at extreme sides; fifth antennal segment much longer than third . . . . *variabilis*	

Collection Records of Species and Varieties

Bombus affinis Cresson

Collection data:

25-V-27 Tippecanoe Co. (queen-Student Collection); 8-VIII-50 Porter Co. (worker-red clover—R. T. Everly).

This species has not previously been reported from Indiana.

Bombus americanorum (Fab.)

Collection data:

Allen, Benton, Brown, Carroll, Clark, Clay, Clinton, Dearborn, Elkhart, Fountain, Gibson, Greene, Harrison, Hendricks, Huntington, Jasper, Jennings, Johnson, Kosciusko, Lake, LaPorte, Lawrence, Marion, Marshall, Miami, Montgomery, Morgan, Orange, Owen, Porter, Posey, Pulaski, Putnam, Randolph, Ripley, Shelby, Steuben, Tippecanoe, Vigo, Wabash, Warren, Warrick, White.

This species is also known as *Bombus pennsylvanicus* (DeG.). Very common.

Bombus auricomus (Robt.)

Collection data:

Allen, Benton, Boone, Clark, Dearborn, Elkhart, Fountain, Greene, Hendricks, Jasper, Jennings, Knox, Kosciusko, LaGrange, Lake, Marion, Marshall, Miami, Montgomery, Morgan, Owen, Pike, Porter, Pulaski, Putnam, Ripley, Rush, Starke, Tippecanoe, Tipton, Warren.

This is one of our most common species.

Bombus bimaculatus Cresson

Collection data:

Clark, Dearborn, Fountain, Marion, Morgan, Ripley, Sullivan, Tippecanoe, Warren.

This species is more common than collection data shows. It is probably the first bumblebee to be seen in the spring.

Bombus borealis Kirby

Collection data:

7-VI-50 Marshall Co. (queen-hairy vetch-Michael Chandler).

This is the first record of this species from Indiana. Another queen of this species was observed one week later at this same location but was apparently killed by flying through a prebloom alfalfa spray which was being applied.

Bombus fervidus Fab.

Collection data:

Allen, Clark, Elkhart, Fountain, Howard, Huntington, Jennings, Kosciusko, LaGrange, LaPorte, Madison, Marshall, Noble, Owen, Parke, Pulaski, Steuben, Tippecanoe, Wabash.

This is a common species in northern Indiana.

Bombus fervidus var. *dorsalis* Cresson

Collection data:

?-1943 Blackford Co. (queen-Purdue Student Collection); 20-X-49 Tippecanoe Co. (male-Purdue Student Collection); 31-VIII-50 Jasper Co. (male-red clover-R. T. Everly).

Since the typical *Bombus fervidus* integrades into this variety, it should be taken in the counties where *Bombus fervidus* occurs. It is quite rare.

Bombus fraternus (F. Smith)

Collection data:

?-VI-15 Marion Co. (worker-H. F. Dietz); 28-X-50 Posey Co. (queen-B. E. Montgomery).

Although this species has been previously recorded from the state by Franklin (3), its occurrence seems to be so rare as to warrant the above data.

Bombus griseocollis (De Geer)

Collection data:

Allen, Benton, Clark, Dearborn, Fountain, Greene, Hendricks, Jasper, Johnson, Lake, Marshall, Miami, Montgomery, Morgan, Owen, Parke, Porter, Pulaski, Ripley, Starke, Tippecanoe, Tipton, Wabash, Warren, Warrick, White.

This is one of our most common species. Until very recently this species was known as *Bombus separatus* Cresson.

Bombus impatiens Cresson

Collection data:

Adams, Allen, Benton, Brown, Clark, Daviess, Dearborn, Elkhart, Fountain, Greene, Harrison, Hendricks, Huntington, Jasper, Jennings, Kosciusko, LaGrange, Lake, LaPorte, Lawrence, Marion, Marshall, Montgomery, Morgan, Noble, Orange, Owen, Parke, Porter, Posey, Pulaski, Ripley, Starke, Sullivan, Tippecanoe, Warren, White.

A very common, if not the most common, bumblebee in Indiana.

Bombus perplexus Cresson

Collection data:

3-V-30 Tippecanoe Co. (queen-Purdue Student Collection).

This is the only record of this species from Indiana. The specimen runs to Color Variant 1 in Franklin since the pleurae is covered with yellow pile to the bases of the legs. This species has a distinctive shade of yellow, having somewhat of an orange cast.

Bombus ternarius Say

Collection data:

Say, in his original description, noted "Inhabits Indiana". I know of no other record of this species from the state.

Bombus vagans F. Smith

Collection data:

Allen, Clark, Jasper, Jennings, LaGrange, Lake, Marion, Marshall, Parke, Porter, Ripley, Starke, Tippecanoe.

This is a common species.

Bombus vagans var. *helenae* Frison

Collection data:

2-VII-50 Ripley Co. (male-red clover-Leland Chandler); 12-VIII-50 Clark Co. (male-B. E. Montgomery).

This variety occurs with the typical species and has the same range of distribution. It seems to be rare in the state.

Psithyrus ashtoni (Cresson)

Collection data:

Two males in the Purdue University collection were determined to be this species by Dr. Milliron. Both specimens bear labels which are practically illegible. It is entirely possible that these specimens did not come from within the state but if so, they are from Cass Co.

Plath (6) states that *Psithyrus ashtoni* is an inquiline in the nests of *Bombus affinis* and *Bombus terricola.* Since the latter species has not been taken in the state and the former has been taken but twice, this species of *Psithyrus* must occur rarely if at all.

Psithyrus insularis (F. Sm.)

Collection data:

Two unlabeled female specimens in the Purdue University collection were determined to be this species by Dr. Milliron. This species is included in the hope that further collecting will establish a definite record from Indiana. Milliron (5) reports that the host is unknown in Michigan.

Psithyrus laboriosus (Fab.)

Collection data:

Carroll, Clark, Harrison, Lake, Madison, Owen, Ripley, Tippecanoe, Warren.

Plath (6) reports it as being an inquiline in the nests of *Bombus vagans* and *Bombus impatiens.* This is a very common species.

Psithyrus laboriosus var. *citrinus* (F. Sm.)

Collection data:

Adams, Carroll, Clark, Tippecanoe.

This variety is reported by Bequaert and Plath (1925) to be an inquiline in the nests of *Bombus vagans* and *Bombus impatiens.* It appears to be fairly common.

Psithyrus variabilis (Cresson)

Collection data:

Benton, Boone, LaGrange, Lake, Marion, Morgan, Montgomery, Sullivan, Tippecanoe, Warren, Wayne.

This is the most common species of *Psithyrus* in Indiana. Plath (6) states that this species is an inquiline in the nests of *Bombus americanorum.*

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Insects of Indiana for 1950

J. J. Davis, Purdue University

Weather always plays a major part in insect abundance or scarcity and conditions which may favor one insect may be unfavorable to another and vice versa.

Mild weather prevailed early but during May and the greater part of June the weather was cold and unfavorable for some insects, particularly the corn borer. Cold and wet weather also prevailed during August and September, in fact many insects showed indications of early hibernation. A warm spell in October lasting over two weeks reactivated many insects. In general, however, the season was unfavorable for many of our major insects, particularly field crop insects, flies, pollinating insects, etc.

Cereal and Forage Crop Insects

Chinch bugs (*Blissus leucopterus* Say) showed up conspicuously in six northeastern and three northwestern counties, for the first time in a number of years. Although the outbreaks were scattered and the damage not great, nevertheless it forecasts possible increase and destructiveness in 1951.

Spittle bugs (*Philaneus leucophthalmus* L.) were again abundant and were in conspicuous numbers in the southern half of the State as well as in the northern half. This insect has, in fact, become one of the major pests of forage crops in indiana. Many plants, both wild and cultivated, were attacked and damage and abundance was especially noticeable on legumes and strawberry. Of the legumes, red clover, alfalfa, and sweet clover, were most commonly attacked, causing deformity of the terminal shoots and, because of the spittle, preventing proper curing of hay. On strawberries the spittle was messy and hurt the appearance of the marketed berries.

Sweet clover weevil (*Hypera cylindricollis* Fahr.) is a serious pest in many parts of Indiana, especially in the western part of the State where sweet clover is a major soil-improvement crop. This weevil was also found feeding on alsike and red clover. There is evidence that the species has spread to the south end of the State.

The northern (*Diabrotica longicornis* Say) and southern (*D. 12-punctata* Fab.) corn root worm adults were very destructive to corn in the bottom lands along the Ohio, White, and Wabash rivers in southwestern. Indiana, where they are known as silk beetles, because they eat off the green silks of corn, preventing fertilization of the grains. Airplane spraying with DDT has given good results.

The European corn borer (*Pyrausta nubilalis* Hon.) wintered over in larger numbers than for several years but delayed corn planting and

unfavorable weather were responsible for a decrease in abundance and destructiveness, excepting in extreme southern parts of the State.

Wheat jointworm (*Harmolita tritici* Fitch) showed an increase over 1949 and was responsible for considerable losses. Furthermore, the increase resulted in a marked and serious increase of the straw itch mite (*Pediculoides ventricosis* Newp.) which is predaceous on the jointworm. It would appear from the abundance of the mite that there may be a decrease in jointworm in 1951.

The potato leafhopper (*Empoasca fabae* Harr.), was very abundant, especially in the northern half of the State, causing a yellowing of the foliage of alfalfa and noticeably reducing the seed yield as well as the forage.

Caterpillars (armyworm, *Cirphis unipuncta* Haw.; fall armyworm, *Laphygma frugiperda* S. and A.; and corn earworm, *Heliothis obsoleta* Fab.) were abundant and destructive in many parts of the State, especially in the southern half.

Vegetable Insects

An onion aphid (*Micromyzus formosanus* Tak.) was sent in from Brownstown in southern Indiana where it was reported very abundant on onion. This species was described from Formosa and in 1935 Essig reported it as a new species *(M. alliumcepa)* from California. Apparently it has not been found previous to its occurrence in Indiana, since its discovery in California.

Potato flea beetle (*Epitrix cucumeris* Harr.) was destructive in May and June to small direct seeded and new transplanted tomatoes.

Mexican bean beetle (*Epilachna varivestis* Muls.) showed an increase over recent years.

The bean leaf beetle (*Cerotoma trifurcata* Forst.) was quite abundant early in the season and a second generation appeared the last of July and August. In addition to beans, red clover and soybeans were slightly attacked.

Cabbage maggot (*Hylemyia brassicae* Bouchè) is on the increase on cabbage in the spring and turnips and radishes in the fall. In the Indianapolis area as high as 75 percent of fall turnips are infested.

Aphids were unusually abundant on various crops including tomato, potato, turnip, cabbage and melon.

Hornworms (*Protoparce sexta* Johan, and P. *quinquemaculata* Haw.) were apparently not as generally abundant as last year but there were regions where they were very destructive.

The greenhouse centipede (*Scutigerella immaculata* Newp.) affectionately known as galloping elephants or galloping dragons by greenhouse vegetable growers, has been on the increase the past three years and is giving greenhouse growers much concern.

Fruit Insects

With the rather general use of parathion on peaches, most of the

pest problems have been solved. These include Oriental fruit moth (*Laspeyresia molesta* Busck), plum curculio (*Conotrachelus nenuphar* Herbst), mites (*Paratetranychus pilosus* C. and F. and *Tetranychus telarius* L.) and aphids (*Myzus persicae* Sulz.) However the plant bugs, which blemish the fruit, known as catfacing, are still major and unsolved problems. Also the lesser peach tree borer (*Synenthedon pictipes* G. and R.) is on the increase and becoming a major pest.

On apple the major pest, codling moth (*Carpocapsa pomonella* L.), is at low level, perhaps largely because of the general use of DDT. The mild weather this fall permitted a build-up and they are going into winter quarters in moderately large numbers. Mites, of the two species referred to above, seem to be more widespread than in previous years but have not built up appreciably, probably because of the cool and wet summer and a better knowledge of control on the part of the growers. Plum curculio was serious in many orchards causing blemishes on the fruits. In northern Indiana the apple maggot (*Rhagoletis pomonella* Walsh) was more abundant than usual.

In southwestern Indiana the 13-year brood of the 17-year cicada (*Magicicada septendecim* L.) made its appearance in very large numbers, damaging trees by the egg slits made in the branches, causing them to break over.

Forbes scale (*Aspidiotus forbesi* Johns.) has become an outstanding pest in southern Indiana and is superceeding the San Jose scale as the major scale pest in orchards.

The rose chafer (*Macrodactylus subspinosus* Fab.) was unusually abundant and destructive, especially in the northern part of the State, attacking apples, grapes, and roses as well as other plants.

Shade Tree Insects

Aphids of various species were exceptionally abundant the past year on oak, elm, maple, tulip tree, and willow, resulting in honey dew deposits on leaves, development of sooty mold fungus, attractive to flies, spotting of automobiles, and premature dropping of leaves.

Walking sticks (*Diapheromera femorata* Say) again defoliated a 30-acre oak woodlot in Starke County.

Bagworms (*Thyridopteryx ephemeraeformis* Haw.) were very abundant in central and southern Indiana, and were especially destructive to junipers and arbor vitae. For the first time they were found in the extreme northern end of the State.

The fall webworm (*Hyphantria cuneae* Dru.) is commonly abundant in southern Indiana, but this year it has been abundant in northern, as well as southern Indiana.

The oak twig pruner (*Ellaphidon villosum* Fab.) was conspicuously abundant in northern Indiana.

Phloem necrosis (carried by the elm leafhopper *Scaphoideus luteolus* VanD.) and Dutch elm disease carried by the European elm bark beetle (*Scolytus multistriatus* Marsh), continue to take a heavy

toll of American elms. The publicity given to these two diseases has resulted in itinerant "tree doctors" with all kinds of remedies.

Red spiders (*Tetranychus telarius* L.) were abundant and destructive, especially on evergreens.

The strawberry root weevil or crown girdler (*Brachyrhinus ovatus* L.) was reported seriously injuring yew (Taxus) plantings in northern Indiana.

The bronze birch borer (*Agrilus anxius* Gory) has been more destructive, according to reports, than for many years.

The locust leaf miner (*Chalepus dorsalis* Thunb.) was more widely distributed in the south end of the State than in the past.

Stored Grain Insects

The Angoumois grain moth (*Sitotroga cerealella* Oliv.) has become a serious problem in the southern half of the State, no doubt due to large grain surpluses and mild winters the past two years. Especially serious are the infestations of popcorn and hominy corn, because such infestations represent adulteration under the Food and Drug Administration regulations. For the first time, according to our records it caused field infestations of wheat in southern Indiana. Furthermore, the larvae are hosts of the straw or grain itch mite which has been so annoying the past fall.

Bran beetles (*Tribolium confusum* Duv., *Oryzaephilus surinamensis* L., etc.) have been a serious problem in Clinton and Benton oats, two new varieties. The trouble can be attributed to the fact that the two varieties of oats referred to require a week or ten days longer to mature than other varieties, but growers are cutting them the same time as their other fields. Therefore, they are thrashed and stored at a rather high moisture content and thus are susceptible to infestation.

Annoying and Home Pests

Oats bugs (*Anaphothrips striatus* Osb.) were unusually abundant. Complaints referred not only to their irritations but also to the fact that they came through house screens and got into foods being prepared in kitchens.

The clover mite (*Bryobia praetiosa* Koch) was a very annoying pest the past spring, migrating into homes.

Hackberry is one tree commonly used to replace elms being killed by Dutch elm disease and phloem necrosis. This may result in the appearance of a new annoying pest, since it has been observed that the adult psyllids emerging from hackberry leaf galls get into homes, through screens, sometimes in enormous numbers.

Termites have been the subject of many inquiries as usual. Our principal concern is dealing with the questionable and fraudulent commercial operators who have taken thousands of dollars from Indiana citizens. At Purdue we have rather complete information on the dependable and questionable operators and can give information regarding them.

Powder post beetles (Lycertidae) are major pests throughout the state.

Cockroaches are still the number one household pests, judging from the number of inquiries received.

The cluster or attic fly (*Pollenia rudis* Fab.) was frequently reported last spring and already this fall reports are being received. As is generally known this fly is a parasite of earthworms and in seeking winter quarters, frequently enters homes where it remains semi-dormant, coming out as sluggish and annoying flies in the fall, winter or spring, as warmth (natural or artificial) activates them.

Miscellaneous Insects

During the past year or two the Entomology Department at Purdue has given more attention to legume seed production through the control of destructive insects and utilization of beneficial forms. These studies show real promise in increasing legume seed production. An interesting observation in connection with these studies is the apparent increase in bumble bees. For a number of years bumble bees, of major importance in red clover pollination, have been on the decrease, but in 1950, for reasons not yet known, the bumble bee population has definitely increased.

The 1950 Epidemic of the Straw Itch Mite

J. J. DAVIS, Purdue University

The straw or grain itch mite is predaceous on the larvae of various insects, especially the Angoumois grain moth and wheat joint worm.

Some 40 years ago this mite (*Pediculoides ventricosus* Newp.) was a serious problem in the central west (Ohio, Indiana and Illinois) and especially in the southern half of these states. Since that time this mite gave little concern because of its scarcity. In 1950, beginning the latter part of August, reports began coming in from southern Indiana. Letters, telegrams and long distance telephone calls from farmers, county agents, physicians, and veterinarians gave evidence of the abundance and seriousness of this epidemic. For the most part the problem was one affecting humans, although there was evidence that some domestic animals were affected.

The problem at first concerned only farmers handling straw and grain. During the Indiana State Fair, the problem was emphasized because the boys sleeping in the 4H Club Building spread their bedding on straw-covered floors and soon were covered with conspicuous welts produced by the mites. Soon thereafter the infestation spread to straw board factories, the persons handling straw becoming infested and in some cases they walked off the job and refused to return.

The explanation of this epidemic of itch mites is simple. For the past few years surpluses of grain have been held over from one year to another and the mild winters in recent years has permitted successful over-wintering of the Angoumois grain moth. Also for one reason or another, the wheat joint worm has been increasing for the past three years. The increase in the abundance of the two principal hosts of the itch mite is sufficient evidence to explain why the straw itch mite has become a major problem.

It has been many years since a similar serious infestation of mites has occurred in Indiana and the explanation has been given, namely the increase of Angoumois grain moth and the wheat joint worm.

Doctors Scharnberg and Goldberger were among the first to study dermatitus produced by the straw itch mite and in 1909 (Public Health Reports, vol. 24, no. 28, July 9, 1909) published the first exact information we have relative to the itch mite epidemics. In 1910, F. M. Webster published the most complete account as Circular 118 of the U. S. Bureau of Entomology, under the title "A Predaceous Mite Proves Noxious to Man."

One of the earliest remedies suggested was bathing in warm soapy water, followed by applications of talcum powder. This recommendation still holds.

Other suggestions which we have made include a vanishing cream

ointment with ½ per cent of high gamma benzene hexachloride (Kwell), sulphur ointment and dimethyl phtalate, the latter primarily as a repellent and preventive.

To protect workers in straw and grain products, any of the above products seem effective. It has also been suggested that bailed straw and straw for bedding, as well as grain, may be treated with dusting sulphur or benzene hexachloride dust as a preventive.

Control of the Meadow Spittlebug on Forage Crops

RAY T. EVERLY, Purdue University

The meadow spittlebug, *Philaneus leucophthalmus* (L.), is a native insect and until the past decade was of little economic importance. Since 1940 it has increased in abundance and occurs in destructive numbers as far south as Virginia. Today it should be classed as one of the major forage crop pests in the states north of the Ohio River and east of the Mississippi. Increases in forage yields as great as one ton per acre have been reported when this insect was controlled.

The meadow spittlebug has one generation a year. The eggs are laid in old grain stubble in the hay fields in the late summer, usually September and October. In late April or early May, depending on the temperatures, the eggs begin to hatch and hatching occurs over a period of several weeks. The young nymphs are small and the amount of spittle produced is inconspicuous. In late May and Early June the nymphs are nearly full grown and the characteristic spittle masses are easily observed, each mass containing from one to 12 or more nymphs. By the middle of June the adults emerge from the spittle masses. These adults remain on the host plants for several weeks or until the forage crops are cut for hay, which causes them to disperse to adjoining crop areas. Adults can readily be observed on any growing crop during the summer months.

Injury is caused to plants by the nymphs sucking the plant juices from the stems and leaves, the excess liquid passing through the body and forming a frothy saliva-like mass which surrounds the nymph during its developmental period and from which the insect derives its name. Plant growth is stunted. In some plant a typical hormone-like effect is produced. In others internodal development is arrested producing a "bunchy" type of growth. This may be due to the injection of toxic salivary secretions into the plant tissues while feeding, as is the case of many related species of insects. It is suggested that the loss in forage is greater in dry weather than in seasons of abundant moisture, as the feeding of the nymphs draws off liquids from the plants faster than it can be replaced when the soil moisture is at a relatively low level. Populations as great as 300 nymphs per square foot have been observed.

Natural enemies are not numerous as the insect is protected from predators and parasites by the spittle mass surrounding the nymphs.

With the advent of DDT and other organic insecticides with a period of residual toxicity, control of this insect became feasible. However, complications caused by the danger of contamination by these insecticides of food products from animals feeding on treated forage, necessitates caution in recommendations for their use. Also the

presence of other injurious insects on forage crops which can be controlled by these insecticides should be taken into consideration in recommendations.

Experiments on the control of this insect were of three types; application of dilute dusts in early spring, the use of emulsifiable forms of insecticides in low gallonage applications, and the effects of various forms of insecticides on the adult insect in the summer.

In 1949, dilute dusts were applied to red clover near Wingate, Indiana, on May 4. The reductions in populations, as measured by the residual adult insects present in mid-June, indicated that benzene hexachloride, toxaphene and methoxychlor gave the best control. DDT, chlordane, and parathion gave highly significant reductions, but were not as effective as the other materials.

In 1950, thirteen emulsifiable forms of insecticides were applied to plots of mixed hay on the Agronomy Farm, near Lafayette, Indiana, on May 13, when spittle masses were numerous on the plants. Counts of the numbers of nymphs per square foot were made on June 6. Dieldrin, methoxychlor, benzene hexachloride, and lindane gave the best control. DDT and toxaphene were also effective. Chlordane, aldrin, Dilan, TDE (Rhothane), rotenone, Fluo-DDT (fluorine analog of DDT), and colloidal DDT were either ineffective or gave insufficient control to be of any value.

Since little is known of the injurious effects of the feeding of adult spittlebugs, the necessity for controlling them may be questionable. Also, it is doubtful if control of these insects to prevent oviposition will be of value. However, information has been obtained from experimental applications of various insecticides to clover in the summer, on the effects of these materials on the adult spittlebug populations.

In 1949, when adult populations averaged 16 spittlebugs per 10 sweeps of a 15-inch net, emulsions of methoxychlor and CS645A (one of the active ingredients in Dilan) gave the greatest reduction in the number of adults eight days after applications. Emulsions of DDT, benzene hexachloride, chlordane, toxaphene, TDE (Rhothane), Fluo-DDT (fluorine analog of DDT) and various mixtures of the above gave no practical control of the adults, although the DDT, benzene hexachloride, and mixtures containing combinations of methoxychlor, chlordane, benzene hexachloride, and DDT, reduced the populations of adults a significant amount.

The results of similar tests in 1950, when the average adult spittlebug population was the same as in 1949, (16 per 10 sweeps of a 15-inch net), emulsions of DDT, methoxychlor, lindane, TDE (Rhothane), and wettable parathion gave good reductions in the numbers of adults in the plots four days after application. Emulsions of chlordane, Fluo-DDT (fluorine analog of DDT), aldrin, Potosan, and Systox, and wettable EPN gave no practical control, although chlordane, Fluo-DDT, and aldrin reduced the populations a significant amount.

Preliminary Tests with Systemic Insecticides[1]

GEORGE E. GOULD, Purdue University

A systemic insecticide is one that is absorbed by the plant and translocated in the sap so that parts of the plant other than those treated become toxic to sucking insects. This type of insecticidal action was demonstrated for selenium compounds by Gnadinger (1) and others as early as 1933. These compounds were never used extensively as quantities of the material dangerous to humans accumulated in sprayed plants or in plants grown in treated soils. Recently German chemists have developed a number of phosphorus compounds that show systemic action. In our tests three of these compounds have been tried in comparison with three related phosphorus compounds for which no systemic action has been claimed.

The development of these systemic and other phosphorus compounds have been based on the discoveries of the German chemist Schrader in 1942 (German patent 720,577). After World War II this information became available to the Allied Governments and soon numerous compounds were released for experimental purposes. At present three of the non-systemic compounds, parathion, hexaethyl tetraphosphate and tetraethyl pyrophosphate, are available commercially. The first of the systemics tested was C-1014, a formulation similar to Pestox 3 (octamethylpyrophosphoramide) which has been used in England. The other two in our tests were Systox with its active ingredient belonging to a trialkyl thiophosphate group and Potasan, diethoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin. Two additional phosphorus compounds used in some tests included Metacide, a mixture containing 6.2% parathion and 24.5% of O, O-dimethyl O-p-nitrophenyl thiophosphate, and EPN 300, ethyl p-nitrophenyl thionobenzine phosphonate.

Parathion (O,O-diethyl O-p-nitrophenyl thiophosphate) was the first available for experimental use in 1947 and was found to be quite effective against many insects. In the laboratory a median lethal dose (M.L.D. 50) for the female German roach was .042 percent of the active ingredient as compared to 1.1 percent for DDT and 13.5 for sodium fluoride (Gould 2). In the field a parathion spray killed 100 percent of the grasshopper nymphs on corn in one hour, whereas chlordane, benzene hexachloride and toxaphene required 48 hours for the maximum kill. In the untreated area of this field the nymphs migrated through and severely damaged the first 150 rows of corn, while all treatments stopped the migration.

Against the striped cucumber beetle parathion gave a complete kill within one hour and even prevented the dispersal of beetles that

[1] Systox, Potasan and Metacide were furnished by the Pittsburgh Agricultural Chemicals Co., C-1014 by the Dow Chemical Co., parathion by the American Cyanamid Co., and EPN-300 by duPont & Company.

follows applications of most dusts. This material has given excellent control of plant lice and red spider in numerous tests on many vegetable crops. In one test against the potato aphid on tomatoes the population stayed at a low level for 21 days after treatment, whereas on other treated plots the numbers started increasing again in seven to 10 days. Against the European corn borer on sweet corn parathion gave a control about as good as DDT. In 1947 parathion gave a 99% reduction of borers and DDT a 91% reduction. In 1948 parathion gave a 97% reduction on borers on the Spancross variety and DDT 94%, and on Golden Cross Bantam parathion gave 92% reduction with DDT 98%. In 1949 on the North Star variety parathion gave a 95% reduction and DDT 93%. Parathion has been used against potato insects where it gave good control but the yield was not as high as that of the DDT plots. Several large potato growers used this material as a substitute for DDT for one or two applications in 1950 when plant lice became abundant. On peppermint plants most insects including the looper and the spittle bug adult were controlled, although spittle bugs reinfested plants within a week. Against onion thrips both a 1% and 2% dust and a spray gave significant increases in yield over the check. Against the following insects parathion was only fair to good: tomato hornworm, cabbage worm, cabbage looper, blister beetles and squash bugs.

Parathion has been used on many plants and at many dilutions. On only two groups of plants, tomatoes and the cucurbits, has any injury been observed and in both cases only the spray caused injury. On small direct-seeded tomato plants the spray caused serious burning. On cucumbers and cantaloupes .25%, .50% and 1.0% dusts caused no injury but the spray caused some burning to small plants. Plants starting to vine had no apparent injury.

Tests with the other materials were made in 1950 and were not as extensive as those with parathion over a four year period. C-1014 was applied three times to sweet corn for corn borer control. This material as a water miscible concentrate containing 63.3% active ingredients was applied at a rate of 4 quarts in 100 gallons of water with a knapsack sprayer so as to thoroughly wet the plants and run down the stalk. At the time of dissection about three weeks later this corn had 380 borers per 100 plants as compared with 124 on the untreated. Five applications of C-1014 at this dilution had no influence on the striped cucumber beetle population on treated cantaloupes.

The three systemic materials were applied on August 7 to late cabbage at a rate of 2 quarts per 100 gallons. The amount of active ingredients in each spray differed, as C-1014 has 63% active ingredients in the concentrate, Systox emulsion concentrate 32%, and Potasan emulsion concentrate 30.6% Cabbage loopers were not numerous, but cabbage worms were abundant. Counts of dead and live worms were made on August 9. Treatments were repeated on August 20 and September 7. Since three materials were supposed to be absorbed by the

plants, the amount of damage from feeding was evaluated on August 31 and September 18. The figures for each material are given in Table I.

TABLE I. Kill of Cabbage Worms and Damage Evaluation.

	August 9 Percent Dead	August 31 Damage Evaluation	September 18 Damage Evaluation
C-1014	50	274	206
Systox	97	342	126
Potasan	84	326	196
Rotenone dust	100	198	60
Check	0	396	330

These same three materials plus Metacide and EPN 300 were applied to eggplant on August 10 and 30. The first three plus Metacide emulsion concentrate (33.4% active ingredients) were used at 2 quarts per 100 gallons and the EPN-300 wettable powder (27% active ingredients) at 4.8 pounds per 100 gallons. The plants were old, having been set in the field about June 1 and had a serious infestation of red spider, and light to moderate infestations of plant lice and flea beetle. All materials gave excellent control of the lice and red spiders and caused the flea beetles to disappear for about a week after each application. However, two materials, Systox and Potasan, caused serious distortion of the new growth. This injury was the typical hormone-like growth and eventually affected the terminal 8 to 10 inches of the plants. The old leaves were not affected and so with the control of the pests the plants finally produced many normal fruits.

The three systemic materials were compared with rotenone and several other insecticides for the control of various insects on late beans. The Mexican bean beetle, which is a major pest of beans, in home gardens, was present in small numbers on the early plantings. The late planting was made in the same area and about 1000 beetles were released on the small plants. The old plants were then pulled up to force all beetles to feed and lay eggs on the young plants. In place of the usual two applications for bean beetle control, this crop was dusted or sprayed four times on the following dates: August 7, 16, 30 and September 7.

The bean plants were infested with several insects, including the potato leafhopper, the bean leaf beetle, *Colaspis*, the 12-spotted cucumber beetle and the Mexican bean beetle. The bean beetle was not too injurious until in September when the larvae of the released beetles were reaching maturity. Those plots adjacent to the eggplant became heavily infested with red spider. As in the case of eggplant, the two systemics, Systox and Potasan, caused serious distortion of the plants. This distortion was noticeable after the first application and became more pronounced with the later applications. Plants had the typical

distortion of the hormone-like growth and were stunted in size. Plants were not completely killed by the frost of September 24 and on October 20 these plots had a heavy crop of beans.

Harvest of the beans started on September 22 and was finished after frost nipped the upper leaves. Plants on the two systemic plots had a few small pods and many blooms. The average yield of beans from 50 plants were as follows:

Dust B	8.9 pounds
Rotenone dust	7.6 pounds
Check	5.0 pounds
C-1014 spray	6.8 pounds
Systox spray	3.1 pounds
Potasan spray	1.9 pounds

An analysis of variance showed that differences in yield were highly significant and that a difference of 1.9 pounds between any two treatment averages was significant.

The cabbage maggot has become a destructive pest of cabbage, turnips, radishes and related crops in the Indianapolis area. In September a number of treatments, including C-1014, were applied to turnip seedlings when they first appeared above ground. C-1014 was applied as a spray to and around the small seedlings. In late October the turnips were pulled and many damaged turnips were found in both treated and untreated rows. Plots treated with this material had fewer undamaged turnips than the check.

The squash bug is the one major pest of vegetable crops for which there is no satisfactory control. Five of these new materials were applied in late August to two varieties of squash heavily infested with nymphs of the squash bug. The spray was applied thoroughly to plants and to the ground around the base of the plant. Both Metacide and EPN-300 killed many 12-spotted cucumber beetles in the first 24 hours but the plants were reinfested on the seventh day. These two materials killed some of the squash bug nymphs by contact action, but on the seventh day both adults and nymphs were present in the usual numbers on the plants treated by these two materials and on those treated by the three systemics.

Summary

Three new systemic insecticides were used for the control of several insects and gave good control only against plant lice and red spider. One or all three of the materials were used against the following pests and gave poor results: cabbage worms, European corn borer, cucumber beetle, 12-spotted cucumber beetle, squash bug, Mexican bean beetle and flea beetles. Three related phosphorus derivatives, parathion, Metacide, and EPN-300, gave good control of plant lice and red spider and, except for the squash bug, good to excellent control of the other insects. Two materials, Systox and Potasan, caused serious distortion and stunting on beans and eggplant.

Literature Cited

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The Psocoptera of Indiana

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The published records of psocids from Indiana testify to the fact that the order has been much neglected in the state. I know of no published records before those of Chapman (2) which include only two species—*Lachesilla major* Chapman and *Amphigerontia petiolata* (Banks). Since then Sommerman (4) listed records of four additional species of *Lachesilla*.

From June, 1944, to October, 1950, I have found 57 species of psocids in Indiana. Doubtless additional collecting, especially in the extreme southern part of the state, would add a few species to this number, but in view of the dearth of information it seems advisable to publish my records together with some general notes at this time.

The classification used in this paper is that of Pearman (3), but group names (group is above family) are omitted to save space and the family name Lachesillidae is used instead of Pterodelidae as *Pterodela* is a synonym of *Lachesilla*. I also follow Pearman in the use of the ordinal name, Psoceptera, although most American authors use the name Corrodentia. I am using several of the genera into which the old genus *Psocus* has been split, on the basis of wing venational peculiarities correlating with definite types of genitalia in both sexes. These genera include *Cerastipsocus* Kolbe, *Amphigerontia* Kolbe, *Trichadenotecnum* Enderlein, and *Loensia* Enderlein. The species left in *Psocus* still form groups, however, and some of these may warrant generic distinction. The species in large genera are here listed alphabetically despite their grouping tendencies.

The order Psocoptera is an ancient one, already well differentiated and represented in the Permian. Psocids have apparently experienced difficulty in competition with other tiny herbivores. They must be sought for in such peripheral habitats as rocks, caves, tree trunks, bare branches, dry leaves, and dry grass. A few species have taken to dwelling in man's buildings, and these seem to thrive.

Acknowledgments

I wish to thank Mr. Dale W. Rice of Indianapolis, who has accompanied and aided me on many field trips and has done much collecting by himself, always very generously placing all specimens taken at my disposal.

Dr. Kathryn M. Sommerman of the Army Medical Center, Washington, D. C., has aided in many ways including the verification and correction of many of my determinations.

Dr. W E. Ricker of the Pacific Biological Station, Nanaimo, British Columbia, aided in many ways while at Indiana University. Dr. Shelby D. Gerking of Indiana University has been equally helpful.

Collector's names are not given in the records to save space. Other than the author, those who have collected psocids in Indiana are H. S. Dybas, D. W. Rice, K. M. Sommerman, L. Stannard, R. Traub, and W. F. Turner.

Undescribed Species Listed

An undescribed species of *Psocus* is listed. I do not name and describe this as Dr. Sommerman is now preparing a revision of the genus *Psocus* (sens. lat.) in North America.

I do not name three species of *Liposcelis*. It would be necessary to study the types of the species described from North America before doing this.

FAMILY LEPIDOPSOCIDAE

1. Echmepteryx hageni (Packard)

Amphientomum hageni Packard. Proc. Bost. Soc. Nat. Hist. 13:405, 1870 (Maine and Mass.).

Common on tree trunks and stone bluffs throughout summer and autumn. Runs rapidly and even takes flight to escape capture. Males extremely scarce. An adequate description with figures of wing venation is given by Aaron (1) under the synonym *Echmepteryx agilis.*

Records—Dunes St. Pk. VIII/15/50 (dry leaves) ♀, (oak trunk) ♀. Goshen VII/28/50 (red cedar) ♀. Jasper-Pulaski St. Game Preserve VII/3/50 (oak branches) N. Indpls. VI/30 & VII/1/44 (elm, wild cherry, & pine trunks) 5 ♀; '45: VI/30—VII/26 (deciduous & pine trunks) 5 ♀ 2 N, VII/31 (conifers) ♀; VII/29 & 30/47 (deciduous trunks) 5 ♀. Kosciusko Co.: E. Rd. 30 at Tippecanoe Riv. VII/2/50 (sugar maple trunk) N; Winona Lake VIII/11/47 (elm trunk) 3 ♀; VII/28—VIII/2/48 (deciduous trunks) 8 ♀ 10 N. Oaklandon IX/12/49 (hickory trunk) N. Shades St. Pk. IX/11/50 (stone bluffs) ♀. Turkey Run St. Pk. IX/11 & 12/50 (stone bluffs) ♂ 18 ♀. Yellowwood Lake VII/8 & 10/46 (elm trunks) 2 ♀.

FAMILY TROGIDAE

2. Trogium pulsatorium (Linneaus)

Termes pulsatorium Linneaus, Syst. Nat., ed. 10, p. 610, 1758.

A domestic species becoming a nuisance at times.

Records—Kosciusko Co.: abandoned house 3 mi. N. Warsaw VII/21/50 3 ♀ 17 N; Winona Lake: common throughout summer in buildings of Indiana University Biological Station.

3. Lepinotus sp.

Records—Indpls. VI/20/45 (stored insects) ♀.

FAMILY LIPOSCELIDAE

4. Liposcelis divinatorius (Müller)

Termes divinatorius Müller. Zool. Dan. Prodr. p. 184, 1776.

Records—Indpls. '49: IX/10 (rock dove nest) ♀, IX/11 (stored insects) 20 ♀.

5. Liposcelis niger (Banks)

Troctes niger Banks. Ent. News. 11:559, 1900 (Falls Church, Va.)

A dark brown species occurring under bark of trees.

Records—Bloomington '49: X/11 (under bark dead elm) 5♀, X/20 (under summac bark) ♀; II/12/50 (under *Malus* bark) ♀. Indpls. VII/31/45 (under bark of log) 2 ♀; IX/3/50 (maple bark) ♀. Oaklandon III/5/50 (dead cattail stalk) ♀.

6. Liposcelis sp. No. 1.

A tan species. Meso-metasternal row of 8 to 10 rather long setae; laterals longest. Anterior third of meso-metasternum pale in sharp contrast to posterior portion. Sclerite of subgenital plate (T-shaped structure) with arms each longer than stem. Taken in stored grain.

Records—Indpls. VI/28/45 75 ♀.

7. Liposcelis sp. No. 2.

Color tan. Meso-metasternal row of 7 or 8 setae, shorter than in foregoing species but longer than in *L. divinatorius* or *L. niger*. Apparently a slight transverse ridge just anterior to row. Sclerite of subgenital plate with arms each about same length as trunk. Taken under bark of trees.

Records—Bloomington X/11/49 (under bark dead elm) ♀; V/3/50 (under wild cherry bark) 7 N. Indpls. '45: VII/19 (pine bark) ♀, VII/31 (under bark of log) ♂ 3♀ . Winona Lake VII/14/50 (under wild cherry bark) ♀.

8. Liposcelis sp. No. 3

Head and thorax reddish, abdomen light tan. Taken on large dead grass stem.

Records—Kosciusko Co.: Tippecanoe Riv. at Rd. 15 VII/16/50 N.

9. Embidopsocus needhami (Enderlein).

Troctes needhami Enderlein. Zool. Jahr. Syst. 18:360, 1903 (nr. Virginia, Ill.).

Only females have been taken by the author. Occurs under bark of trees.

Records—Dunes St. Pk. VIII/15/50 (cottonwood trunk ♀ (apterous). Indpls. VI/13, 19 & 24/45 (under apple and hickory bark) 4 ♀ (apterous) 3 N. Lagrange Co.: nr. Howe VII/5/50 (under tamarack bark) 17 ♀ (9 winged, 8 apterous) N.

FAMILY PSOCATROPIDAE

10. Psyllipsocus ramburii selys-Longchamps

Pspllipsocus ramburii Selys-Longchamps. Ent. Mo. Mag. 9:145, 1872 (Paris, France).

A domestic species. I have taken no fully-winged specimens in the state.

Records—Indpls. '45: VII/20 (in cellar) ♀ N, VII/31 (in cellar) ♀; '50: VII/29 (in cellar) ♀, IX/6 (in cellar) ♀. Winona Lake: common throughout summer in buildings of Indiana University Biological Station.

FAMILY EPIPSOCIDAE

11. Epipsocus crosbyanus (Chapman)

Bertkauia crosbyana Chapman. Jour. N.Y. Ent. Soc. 38:364, 1930 (Ithaca, New York).

Occurs exclusively in forest ground litter. Males unknown.

Records—Evansville VI/19/43 ♀. Indpls. IX/13/47 2 ♀ N. Turkey Run St. Pk. IX/11/50 2 ♀. Winona Lake VII/19 & 20/47 5 ♀ 2 N.

12. Epipsocus lepicidinarius (Chapman)

Bertkauia lepicidinaria Chapman. Jour. N. Y. Ent. Soc. 38:363, 1930 (Ithaca, N. Y.).

Occurs exclusively on stone. It has been taken on cement bridges, but only at Turkey Run Park where it is common on the stone bluffs. At that location a male was taken.

Records—Bloomington IX/23/49 3 ♀. Indpls. VII/29/47 ♀. Turkey Run St. Pk. IX/11 & 12/50 (stone bluffs & bridges) ♂ 5 ♀ 5 N.

FAMILY CAECILIIDAE

13. Caecilius aurantiacus (Hagen)

Psocus aurantiacus Hagen. Syn. Neur. N. A. p. 10, 1861.

The most common *Caecilius* in the state. It occurs on both coniferous and deciduous foliage.

Records—Bloomington '49: V/13 (pines & deciduous trees) 4 ♀, V/28 (maple foliage) 2 ♀, X/29 (pine foliage) 2 ♀; V/15 & 23/50 (deciduous foliage) ♂ 2 ♀. Indpls. VI/28/44 (light) ♀; '45: VI/29 (oak foliage) ♀, VII/31 (oak foliage) ♀, VII/3 (conifers & sugar maple) 8 ♀; X/5/46 (spruce foliage) ♀; '47: VII/30 (deciduous foliage) 2♀, IX/13 (deciduous foliage) 7 ♀; VI/8/50 (on window) ♀. Michigan City VI/25/47 (deciduous foliage) 4 ♀. Plymouth VIII/27/48 (deciduous foliage) 3 ♀. Pokagon St. Pk. VIII/19/48 (deciduous foliage) ♀. Shades St. Pk. IX/11/50 (dry leaves, deciduous branches, hemlock foliage) 3 ♂ 9 ♀ N. Turkey Run St. Pk. (hemlocks) 6 ♀. Winona Lake '47: VI/19 (forest ground litter) ♀ 13 N, VI/23 & 30 (deciduous foliage) 6 ♀ N; VII/14/50 (wild cherry foliage) ♀. Yellowwood Lake VI/30/46. ♂.

14. Caecilius confluens (Walsh)

Psocus confluens Walsh. Proc. Ent. Soc. Phila. 2:185, 1863 (Rock Island, Illinois).

Records—Goshen VII/28/50 (red cedar) ♂ ♀. Indpls. IX/3/50 (spruces) 9 ♂ 20 ♀ 7 N.

15. Caecilius pinicola Banks

Caecilius pinicola Banks. Jour. N. Y. Ent. Soc. 11:238, 1903 (Falls Church, Va.).

Occurs only on conifers; adults appear mostly in autumn.

Records—Bloomington IX/23/49 (pines) 10 ♂ 4 ♀; VI/1/50 (pines) ♂ ♀. Indpls. VII/17/45 (cedars) ♂; IX/3/50 (spruces) ♂ 3 ♀. Oaklandon IX/12/49 (pines) 10 ♂ 5 ♀ 7 N. Owen Co.: Green's Bluff

XI/5/49 (hemlocks & red cedars) ♂ 6 ♀ N. Shades St. Pk. IX/11/50 (hemlocks) ♂ 3 ♀ 2 N.

FAMILY POLYPSOCIDAE

16. Polypsocus corruptus (Hagen)

Psocus corruptus Hagen. Syn. Neur N. A. p. 10, 1861 (Dalton, Ga.).

Records—Bloomington X/29/49 (pines) ♀. Indpls. XI/2/46 (bark of log) ♀; '47: VII/30 (deciduous foliage) ♂, IX/13 (deciduous foliage) 2 ♂ 10 ♀. Lake Co.: Shelby VIII/13/47 (deciduous foliage) ♀. Winona Lake VI/23/47 (deciduous foliage) 38 ♂ 40 ♀.

FAMILY LACHESILLIDAE

17. Lachesilla andra Sommerman

Lachesilla andra Sommerman Ann. Ent. Soc. Amer. 39:636, 1946 (Giant City State Park, Ill.).

Restricted to the prairies and Lake Michigan sand dunes where it occurs on grasses, mostly *Andropogon.*

Records—Beaver Lake Prairie V/18/41 23 ♂ 26 ♀ 2 N; V/10/42 5 ♂ 6 N; '50: VII/3 8 ♀ N, VIII/15 3 ♂ 6 ♀ 8 N. Dunes St. Pk. VIII/15/50 3 ♂ 3 ♀ 3 N. Evansville VI/18/43 2 ♂ 2 ♀ N.

18. Lachesilla anna Sommerman

Lachesilla anna Sommerman. Ann. Ent. Soc. Amer. 39:636, 1946 (Giant City State Park, Ill.).

Records—Jasper-Pulaski St. Game Preserve VII/3/50 (dry leaves) ♂. Kosciusko Co.: Fish Lake S. Warsaw VI/23/50 (dry leaves) ♂; 3 mi. SW. Warsaw VIII/6/50 (dry leaves) ♀. Shades St. Pk. IX/11/50 (dry leaves) ♂ 3 ♀ 2 N. Turkey Run St. Pk. IX/11 & 12/50 (dry leaves) ♂ N(?), hemlocks ♂.

19. Lachesilla contraforcepeta Chapman

Lachesilla contraforcepeta Chapman. Jour. N. Y. Ent. Soc. 38:348, 1930 (Sea Cliff, N. Y.)

The most common conifer-inhabiting Lachesilla in Indiana.

Records—Bass Lake VIII/5/49 ♀. Bloomington '49: IX/23 & 24 (pines) 3 ♂ 2 ♀, X/22 & 29 (spruces) ♂ 2 ♀. Bristol VII/3 & 4/47 (red cedar) ♂ 3 ♀. Indpls. VI/18/45 (pines) 13 ♂ 14 ♀ 16 N; XI/5/46 (spruce) ♂. Fish Lake S. Warsaw VI/23/50 (pines) 4 ♂ 4 ♀. Oaklandon IX/12/49 (pines) ♂ ♀. Owen Co.: Green's Bluff XI/5/49 (red cedar) ♂ 3 ♀. Pokagon St. Pk. VIII/18/49 (pines) 7 ♂ 10 ♀. Shades St. Pk. IX/11/50 (hemlocks) 3 ♂ 2 ♀. Stark Co.: Koontz Lake VIII/15/49 (spruces) 3 ♂ 2 ♀ N. Turkey Run St. Pk. IX/11 & 12/50 (hemlocks) ♂ 2 ♀. Whitley Co.: Loon Lake VIII/10/49 (red cedar) ♀.

20. Lachesilla corona Chapman

Lachesilla corona Chapman. Jour. N. Y. Ent. Soc. 38:348, 1930 (Sea Cliff, N. Y.).

Records—Bloomington '49: IX/24 (dry leaves) ♀, X/29 (pines) ♀. Clare VII/26/47 (dry leaves) ♀. Indpls. '45: VI/18 & 27 (dry leaves) 4 ♂ 4 ♀, VI/27 (conifers) ♂ ♀, VII/19 (dry leaves) ♀; X/5/46

(conifers) 3 ♂ 4 ♀; VII/24/48 (dry leaves) 2 ♂ 2 ♀ N; '49:VI/1 (dry leaves) ♂ ♀, IX/11 (dry leaves) ♂ ♀. Jasper-Pulaski St. Game Preserve VII/3/50 (dry leaves) 4 ♂ 7 ♀. Knox Co.: VII/20/38 (peach foliage) ♂. Fish Lake S. Warsaw VI/23/50 (dry leaves) ♂. Winona Lake VIII/14/50 (deciduous foliage) ♀. Shelby VIII/13/47 (dry leaves) ♀.

21. Lachesilla forcepeta Chapman

Lachesilla forcepeta Chapman. Jour. N. Y. Ent. Soc. 38:348, 1930 (Sea Cliff, N. Y.)

Inhabits conifers; rather scarce in the state.

Records—Bristol VII/3 & 4/47 (cedars) 2 ♂ 6 ♀. Fish Lake S. Warsaw VII/24/50 (spruce) 2 ♂. Goshen VII/28/50 (red cedars) 6 ♂ 2 ♀ N. Indpls. VIII/8/50 (Scotch pine) ♂.

22. Lachesilla major Chapman

Lachesilla forcepeta var *major* Chapman. Jour. N. Y. Ent. Soc. 38:349, 1930 (Spottswood, Va.).

Inhabits both conifers and dry leaves. More numerous in Indiana than its close relative *L. forcepeta.*

Records—Bloomington '49: IX/23 & 24 (pines) 3 ♂ 2 ♀, (dry leaves) ♂, X/29 (pines) ♂, XI/6 (dry leaves) ♂ ♀ N. Bristol VII/3 & 4/47 (red cedars) ♂ ♀, (dry leaves) 2 ♂ 6 ♀. Dewart Lake VIII/25/48 (deciduous foliage) ♀. Dunes St. Pk. VIII/15/50 (dry leaves) ♂; VII/24/26 ♂. Indpls. VI/18 & 27/45 (dry leaves) ♂ ♀; X/5/46 (hemlocks) ♂; VI/1/49 (dry leaves) ♂ 3 ♀; VIII/8/50 (dry leaves) 3 ♂ 2 ♀. Jasper-Pulaski St. Game Preserve VII/3/50 (dry leaves) ♂ ♀. Kosciusko Co.: 3 mi. SW. Warsaw VIII/6/50 (dry leaves) ♂ 2 ♀. Oaklandon IX/12/49 (pines) ♂ ♀. Shades St. Pk. IX/11/50 (dry leaves) 2 ♂ ♀.

23. Lachesilla nubilis (Aaron)

Caecilius nubilis Aaron. Proc. Ac. Nat. Sci. Phila. 38:13, 1886 (S. Texas).

Inhabits dry deciduous leaves and corn stalks; sometimes occurs in large numbers at lights.

Records—Beaver Lake Prairie V/18/41 (dry grass) 9 ♀; VIII/15/50 (dry leaves) 2 ♂ 4 ♀ 5 N. Bristol VII/4/47 (red cedars) ♀. Evansville VI/21/43 (light) ♂. Jackson Co. VI/27/38 (willow) ♂. Indpls. VI/17 & 27/44 (light) 9 ♂ 6 ♀; '45: VI/25 (freshly painted surface) ♂ ♀, VI/26 (light) ♀, VI/27—VII/12 (dry leaves) 7 ♂ 2 ♀, VII/13 (dry grass) 2 ♂ 2 ♀, VII/25 (window) ♂. Posey Co.: Pirogue Slough VI/4/50 (corn) ♀ N. Winona Lake VIII/8/48 (in building) ♂.

24. Lachesilla pallida (Chapman)

Terracaecilius pallidus Chapman. Jour. N. Y. Ent. Soc. 38:343, 1930 (Ithaca, N. Y.).

Nymphs and adult females are found only on forest ground litter. Adult males seem to leave this habitat quickly and occur in dry leaves on branches.

Records—Indpls. VI/18/45 (dry leaves) ♂; VII/24/48 (forest

ground litter) ♀; IX/11/49 (dry leaves) ♂. Kosciusko Co.: Gordy Lake VI/12/50 (dry leaves) ♂; Winona Lake '47: VI/23 (deciduous foliage) ♂, VII/20 (forest ground litter) 3 ♀; VIII/8/48 (deciduous foliage) ♂.

25. Lachesilla pedicularia (Linnaeus)

Hemerobius pedicularius Linnaeus. Syst. Nat. ed. 10. p. 551. 1758.

The most abundant Lachesilla in Indiana; occurs in a variety of habitats, including houses.

Records—Bloomington X/11/49 (dry leaves) ♂. Culver VIII/27/48 (light) ♂ 2 ♀. Dunes St. Pk. VIII/15/50 (Scotch pine) 2 ♀, (dry leaves) ♂ 4 ♀, (grass) 2 ♀. Ft. Harrison VIII/12/42 (windows) 7 ♂ 10 ♀. Hoffman Lake VIII/26/48 (willow foliage) ♂. Indpls. VII/16/44 (window) 4 ♂; '45: VI/23 & 27 (dry leaves) 3 ♂ 4 ♀, VI/23 (in house) ♂, VI/25 (freshly painted surface) ♂ 5 ♀, VI/26 (light) 2 ♂ 2 ♀, VI/26 & 30 (apple & elm trunks) ♂ ♀, VII/18 (dry leaves) ♂, VII/19 (freshly painted surface) 2 ♀, VII/20 (conifers) 2 ♀, VIII/2 (window) ♂ 2 ♀. Jasper-Pulaski St. Game Preserve VII/3/50 (dry leaves) ♂. Michigan City VIII/15/50 (dry leaves) 2 ♀. Pokagon St. Pk. VIII/19/48 (deciduous foliage) ♀. Winona Lake VIII/1 & 5/48 (in building) ♂ ♀.

26. Lachesilla rufa (Walsh)

Psocus rufus Walsh. Proc. Ent. Soc. Phila. 2:185, 1863 (Rock Island, Ill.).

An uncommon dry leaf inhabitating species.

Records—Indpls. VI/29/45 (dry leaves) ♂; X/5/46 (spruce) 4 ♂ 3 ♀; VI/1/49 (dry leaves) ♀. Michigan City VI/25/47 (deciduous foliage) 2 ♀. Roselawn V/23/48 ♂. Shades St. Pk. IX/11/50 (dry leaves) ♂ ♀. Winona Lake '47: VII/13 (dry leaves) ♀, VIII/5 (light trap) ♂, VIII/10 (dry leaves) 2 ♀.

FAMILY PERIPSOCIDAE

27. Peripsocus madescens (Walsh) (?)

Psocus madescens Walsh. Proc. Ent. Soc. Phila. 2:186, 1863 (Rock Island, Ill.).

The Indiana specimens differ from the *P. madescens* of Chapman's figure in the shape of the subgenital plate, it being roughly elliptical with the side arms barely protruding beyond the main body. My specimens were all taken on pines, some on Scotch pine, which gives the possibility of introduction from Europe. *P. madescens* has a close relative, *P. alboguttatus*, in Europe.

Records—Bloomington '49: IX/23 & 24 (pines) 2 ♀ N, X/29 (pines) 3 ♀. Indpls. VIII/8/50 (Scotch pine) 2 ♀. Oaklandon IX/12/49 (pines) 3 ♀.

28. Peripsocus madidus (Hagen)

Psocus madidus Hagen. Syn. Neur. N. A. p. 12, 1861 (N. Y.)

The most abundant *Peripsocus* in Indiana; males and females about equal in number. Occurs on deciduous trees, conifers, and to a lesser extent in dry leaves.

Records—Bloomington '49: IX/23 & 24 (pines) ♂, IX/24 (deciduous branches) 2 ♂ 3 ♀, X/11 (deciduous branches) 6 ♀, X/29 (pines) 2 ♂ 5 ♀. Culver VII/2/47 (tamaracks) 2 ♂. Dixon Lake VIII/27/48 (deciduous foliage) ♀. Indpls. '45: VI/15 & 16—VII/9 (deciduous trunks) 17 ♂ 12 ♀ (5 short winged) 38 N, VI/19 (dry brush) 6 ♂ 3 ♀ (short winged) N, VII/17 & 24—VIII/3 (conifers) 7 ♂ 3 ♀, VIII/3 (dry leaves) ♂; X/5/46 (hemlock) ♂; VII/30/47 (cottonwood trunk) ♂ 6 ♀ (3 short winged) 6 N, (tamaracks) ♂ 2 ♀. Manitou Lake VIII/22/48 (deciduous foliage) ♀. Oaklandon IX/12/49 (pines) ♂. Plymouth VIII/27/48 (deciduous foliage) ♂ 3 ♀. Pokagon St. Pk. VIII/19/48 (deciduous foliage) ♂; VII/5/50 (pines) ♀. Shafer Lake VIII/22/48 (deciduous foliage) ♂. Shelby VIII/16/47 (maple foliage) 2 ♂ ♀. Winona Lake '47: VI/23 & 30 (deciduous foliage) ♂ 2 ♀, VI/27—VII/17 (light trap) 5 ♂ ♀; '48: VII/31 (on building) ♂, VIII/4 (light trap) ♂. Yellowwood Lake VII/10/46 (bald cypress) ♀.

29. Peripsocus quadrifasciatus (Harris)

Psocus quadrifasciatus Harris. Ent. Corresp. p. 331, 1869 (Cambridge, Mass.).

Occurs in a variety of habitats from May to November. Males are very scarce.

Records—Bloomington '49: IX/23 & 24 (pines) 3 ♀ 2 N, (deciduous branches) 4 ♀, (limestone) ♀, X/29 (pines) 5 ♀, (deciduous branches) ♀. Indpls. VII/30/47 (maple trunk) 13 ♀ 8 N, (tamarack) ♀; IX/8/49 (box elder branches) ♀. Jasper-Pulaski St. Game Preserve VII/3/50 (oak branches) ♀. Oaklandon IX/12/49 (hickory trunk) 2 ♀, (pines) 5 ♀. Owen Co.: Green's Bluff XI/5/49 (hemlocks) ♀. Shades St. Pk. IX/11/50 (hemlocks) ♂ 5 ♀ 2 N. Turkey Run St. Pk. IX/11 & 12/50 (stone bluffs) 2 ♀, (hemlocks) ♂ 5 ♀. Winona Lake '47: VI/23 & 30 (deciduous foliage) 16 ♀, VIII/4 (deciduous foliage) 5 ♀.

30. Peripsocus stagnivagus Chapman

Peripsocus stagnivagus Chapman. Jour. N. Y. Ent. Soc. 38:376, 1930 (Lake Waccamaw, N. C.)

A rather scarce species occurring in late summer and autumn mostly on trunks of deciduous trees. Males and females about equal in number.

Records—Indpls. '47: VII/30 (deciduous trunks) 7 ♂ 9 ♀, X/4 (birch trunk) ♂ 2 ♀; IX/8/49 (wild cherry trunk) ♂ ♀ 4 N. Oaklandon IX/12/49 (hickory trunk) ♂. Turkey Run St. Pk. IX/11/50 (stone bluffs) ♀.

31. Ectopsocus californicus (Banks)

Peripsocus californicus Banks. Jour. N. Y. Ent. Soc. 11:237, 1903 (Calif.).

Records—Bloomington '49: V/28 (pines) ♀, X/22 (brush pile) ♀.

32. Ectopsocus pumilis (Banks)

Peripsocus pumilis Banks. Bull. Mus. Comp. Zool. 64:313, 1920 (Monticello, Fla.).

A common dry leaf and corn inhabiting species. Adults and nymphs hibernate on corn between the groove and leaf sheath.

Records—Bloomington X/19/49 (in building) ♀. Evansville VI/27/43 (dry leaves) 4 ♂ 5 ♀. Indpls. '44: VI/27 (light) ♀, IX/27—X/3 (on lumber) ♂ ♀; '45: VI/18-29 (dry leaves) 7 ♂ 9 ♀, VII/18—VIII/2 (on windows) 4 ♂ 2 ♀, VII/24 (dry leaves) N; X/5/46 (hemlocks) ♂ ♀; X/4/47 (corn) ♂; VI/1/49 (dry leaves) ♀; II/18/50 (corn) 4 ♂ ♀ N. Fish Lake S Warsaw VI/23/50 (dry leaves) ♂ 2 ♀.

33. Anomopsocus amabilis (Walsh)

Psocus amabilis Walsh Proc. Ac. Nat. Sci. Phila. 14:362, 1862 (Rock Island, Ill.).

Rather common in dry leaves, also occurs on conifers.

Records—Bristol VII/4/47 (red cedars) ♂. Caldwell Lake VIII/18/48 (deciduous foliage) ♀. Fish Lake S Warsaw VI/23/50 (dry leaves) ♂ 5 ♀. Indpls. X/5/46 (spruce) ♂; VI/1/49 (dry leaves) ♂. Michigan City VI/25/47 (deciduous foliage) ♂; VIII/15/50 (dry leaves) ♀. Owen Co.: Green's Bluff XI/5/49 (dogwood branches) ♂. Shades St. Pk. IX/11/50 (dry leaves) ♀ 6 N. Winona Lake VIII/15/47 (dry leaves) ♀; VII/20/49 (brush pile) 5 ♀.

FAMILY PHILOTARSIDAE

34. Philotarsus maculosus (Aaron)

Elipsocus maculosus Aaron. Trans. Am. Ent. Soc. 11:39, 1883 (Philadelphia, Penn.).

Has been taken at Winona Lake where it is quite abundant each year on trunks of a few trees. Adults and nymphs spin heavy webs over themselves; seldom more than three individuals are found under one web. There is a single brood each year; adults appear in late July and August.

Records—Winona Lake '48: VIII/1 (elm trunk) ♂ 2 N, VIII/15 (elm trunk) 8 ♂ 9 ♀ 3 N; '49: VII/20 (stump) 3 ♂ 2 ♀ 5 N, VII/26 (sycamore & cottonwood trunks) ♂ 2 ♀ 6 N.

FAMILY MESOPSOCIDAE

35. Mesopsocus? immunis (Stephens)

Psocus immunis Stephens. Brit. Ent. p. 121, 1836 (Eng.).

Records—Fish Lake S Warsaw VI/26/50 (oak branch) ♀. Winona Lake V/10/48 (on door) ♂.

FAMILY PSOCIDAE

36. Cerastipsocus venosus (Burmeister)

Psocus venosus Burmeister. Handbook Ent. 2:778, 1839.

Nymphs and young adults occur in large flocks on trunks and branches of deciduous trees. Later the adults spread out, flying readily.

Records—Indpls. VIII/7/50 (light) ♀. Elkhart Co.: 4 mi. S. Goshen VII/28/50 (silver maple limb) 27 N. Winona Lake VIII/4/47 (silver maple trunk) ♂; VII/26/49 (silver maple trunk) 18 ♂ 15 ♀; VIII/14/50 (shrubs) 4 ♂ 15 ♀.

37. Amphigerontia petiolate (Banks)

Psocus petiolatus Banks. Bull. Mus. Comp. Zool. 62:4, 1918 (Falls Church, Va.).

Records—Dunes St. Pk. VII/24/26 ♂. Jasper-Pulaski St. Game Preserve VII/3/50 (oak branches) 10 ♂ 22 ♀ 5 N. Indpls. X /5/46 (spruces) 2 ♂. Yellowwood Lake '46: VI/21 (light) ♀, VIII/5 (light) ♀.

38. Amphigerontia montivaga (Chapman)

Psocus montivagus Chapman. Jour. N. Y. Ent. Soc. 38:255, 1930 (Whetstone Gulf, N. Y.).

Records—Bloomington X/13/50 (deciduous branches) ♀.

39. Trichadenotecnum alexanderae Sommerman

Trichadenotecnum alexanderae Sommerman. Proc. Ent. Soc. Wash. 50:169, 1948 (N. Plainfield, N. J.).

Adults are common in late summer on trunks of deciduous trees and stone bluffs. No males have been taken in the state.

Records—Bloomington IX/24/49 (tulip tree trunk) 2 ♀, (limestone) ♀. Indpls. '44: VII/27 (elm trunk) ♀, VII/29 (window) ♀; VII/31/45 (deciduous trunks) 8 ♀; X/5/46 (elm trunk) ♀. IX/8/49 (maple trunk) ♀. VIII/14/50 (maple trunk) 4 ♀. Oaklandon IX/12/49 (pines) 2 ♀, (hickory trunk) 8 ♀ 14 N. Shades St. Pk. IX/11/50 (stone bluff) 2 ♀. Turkey Run St. Pk. IX/11 & 12/50 (stone bluffs & bridges) 31 ♀ 12 N. Winona Lake '47: VII/22 (silver maple trunk) ♀ 13 N, VIII/2 (light trap) 3 ♀, VIII/4 (wild cherry trunk) 2 ♀; VIII/1/48 (elm trunk) ♀. Yellowwood Lake VI/10/46 (oak trunk) ♀.

40. Loensia moesta (Hagen)

Psocus moestus Hagen. Syn. Neur. N. A., p. 11, 1861 (Dalton, Ga.).

An uncommon species found mostly on trunks of deciduous trees.

Records—Indpls. '44: VI/23 (wild cherry trunk) ♀, VII/1 (pine trunk) ♀. Winona Lake '47: VII/13 (light trap) ♂, VIII/4 (deciduous foliage) ♂; VII/7/49 (elm trunk) ♀; VII/5/50 (elm trunk) ♀.

41. Psocus atratus Aaron

Psocus atratus Aaron. Trans. Am. Ent. Soc. 11:39, 1883 (Philadelphia, Pa.).

Records—Indpls. VII/29/47 (hackberry trunk) ♂ ♀. Kosciusko Co.: 3 mi. S.W. Warsaw VIII/6/50 (elm trunk) ♀; Winona Lake VIII/11/47 (elm trunk) ♂; VII/29/48 (elm trunk) ♂; VII/20/49 (elm trunk) ♂.

42. Psocus bisignatus banks

Psocus bisignatus Banks. Proc. Ent. Soc. Wash. 6:203, 1904 (Falls Church, Va.).

Records—Indpls. VII/18/44 (wild cherry trunk) ♂; '45: VI/26 (conifers) ♂, (shrubs) ♂, VII/24 (conifers) ♀, VIII/3 (conifers) 2 ♀; IX/1/50 (light) ♂. Stone Lake nr. LaPorte VII/15/49 (elm branches) ♂.

43. Psocus floridanus Banks

Psocus floridanus Banks. Trans. Am. Ent. Soc. 32:2, 1905 (Biscayne Bay, Fla.).

Records—Dunes St. Pk. VII/15/50 (maple trunk) ♀.

44. Psocus infumatus Banks
Psocus infumatus Banks. Jour. N. Y. Ent. Soc. 15:165, 1907 (Falls Church, Va.).
Inhabits bare branches of deciduous trees.
Records—Bloomington '49: IX/23 & 24 (deciduous branches) 3 ♂ ♀, X/11 (deciduous branches) 4 ♀. Kosciusko Co.: E. Rd. 30 & Tippecanoe Riv. VII/2/50 (maple branches) 2 ♂ 4 N. Shades St. Pk. IX/11/50 (dry leaves) ♂.

45. Psocus leidyi Aaron
Psocus leidyi Aaron. Proc. Ac. Nat. Sci. Phila. 38:15, 1886 (Philadelphia, Pa.).
Found mostly on trunks of deciduous trees.
Records—Bloomington IX/24/49 (deciduous trunks) 2 ♂ 6 ♀ 4 N, (pine limbs) ♂. Dunes St. Pk. VIII/15/50 (deciduous trunks) 2 ♀. Winona Lake '47: VII/22 (wild cherry stump) 2 ♂ ♀ 2 N, VIII/4 (wild cherry trunk) 2 ♀; VII/14/50 (wild cherry trunk) ♂ 3 ♀ 5 N.

46. Psocus lichenatus Walsh
Psocus lichenatus Walsh. Proc. Ent. Soc. Phila. 2:183, 1863 (Rock Island, Ill.).
Records—Turkey Run St. Pk. IX/12/50 (bridge) ♀.

47. Psocus lithinus Chapman
Psocus lithinus Chapman. Jour. N. Y. Ent. Soc. 38:249, 1930 (Ithaca, N. Y.).
Inhabits stones, bridges, and branches of deciduous and coniferous trees.
Records—Hoffman Lake VIII/26/48 (willow foliage) ♂. Indpls. IX/8/49 (box elder branches) ♂ ♀; '50: VIII/8 (Scotch pine) ♂, IX/5 (bridge) ♀. Turkey Run St. Pk. IX/11 & 12/50 (hemlocks) 2 ♀, (stone bluffs) ♂ 9 ♀ 17 N. Winona Lake '47: VII/9 (on door screen) ♀, VII/11 (box elder foliage) ♀; VII/14/50 (deciduous trunks & branches) 3 ♀.

48. Psocus nr. lithinus
One of the commonest members of the genus in the state. Inhabits trunks of deciduous tree.
Records—Bloomington IX/23/49 (deciduous branches) 2 ♀. Indpls. '44: VII/1 & 22 (wild cherry trunks) ♂ 3 ♀ N; '45: VII/12 & 20 & VIII/3 (deciduous trunks) 2 ♀ N; VII/30/47 (silver maple trunk) 3 ♀ N. Plymouth VIII/27/48 (deciduous foliage) ♂ 3 ♀. Simonton Lake VIII/25/48 (wild cherry trunk) 8 N. Winona Lake VII/30/47 (deciduous foliage) ♀; VII/28 & 29/48 (deciduous trunks) 13 ♀ 2 N.

49. Psocus novaescotiae Walker
Psocus novaescotiae Walker. Cat. Neur. Brit. Mus., p. 485, 1853.
This species is particularly fond of bare pine branches. It also occurs on deciduous trees.

Records—Indpls. IX/5/50 (pines) ♂. Jasper-Pulaski St. Game Preserve VII/3/50 (deciduous branches) 8 ♂ 2 ♀ 9 N, (pines) 4 ♂ ♀ N. Oaklandon IX/12/49 (pines) 2 ♂ 5 ♀. Pokagon St. Pk. VIII/18/49 (pines) 2 ♀ 3 N. Shades St. Pk. IX/11/50 (stone bluffs) N. Winona Lake VII/13/47 (deciduous foliage) ♂ ♀; VII/14/50 (hickory branch) ♂.

50. Psocus oppositus Banks

Psocus oppositus Banks. Jour. N. Y. Ent. Soc. 15:165, 1907 (Falls Church, Va.).

Occurs on branches of deciduous trees.

Records—Bloomington '49: IX/24 ♀, X/11 ♀. Shades St. Pk. IX/11/50 3 ♀ 3 N.

51. Psocus pollutus Walsh

Psocus pollutus Walsh. Proc. Ac. Nat. Sci. Phila. 14:361, 1862 (Rock Island, Ill.).

Prefers dead pine branches; also occurs on deciduous branches.

Records—Bloomington '49: X/11 (deciduous branches) 2 ♀, X/29 (pines) ♀. Dunes St. Pk. VIII/15/50 (deciduous branches) ♀. Indpls. VII/11/49 (deciduous foliage) ♀. Oaklandon IX/12/49 (pines) 7 ♀.

52. Psocus purus Walsh

Psocus purus Walsh, Proc. Ac. Nat. Sci. Phila. 14:361, 1862 (Rock Island, Ill.).

Records—Dunes St. Pk. VIII/15/50 (deciduous trunks) 3 ♂ ♀ 3 N. Shades St. Pk. IX/11/50 (hemlocks) N. Winona Lake VII/19/49 (cottonwood trunks) 7 ♂ 6 ♀ 10 N. Yelowwood Lake VII/21/46 (hickory trunk) ♀ 5 N.

53. Psocus quietus Hagen

Psocus quietus Hagen. Syn. Neur. N. A., p. 12, 1861 (N.Y.).

Records—Bloomington '49: IX/23 & 24 (deciduous branches) ♂ N, X/11 (deciduous branches) 2 ♂ 3 ♀. Shelby VIII/13/47 (light) ♀. Winona Lake VIII/14/50 (deciduous foliage) ♀.

54. Psocus striatus Walker

Psocus striatus Walker. Cat. Neur. Brit. Mus., p. 486, 1853.

Records—Bloomington IX/23/49 (deciduous branches) ♂. Clare VII/26/47 (light) ♂. Dunes St. Pk. VIII/15/50 (cottonwood trunk) ♀. Indpls. VII/25 & 27/44 (wild cherry trunk) 6 ♀; '45: VII/17 & 20 (wild cherry trunk) 5 ♂ 8 ♀, VII/25 (light) ♀, VIII/3 (conifers) 3 ♂; VII/29/47 (blue ash trunk) ♀. Winona Lake VIII/16/48 (light trap) ♂.

55. Psocus subquietus Chapman

Psocus subquietus Chapman. Jour. N. Y. Ent. Soc. 38:279, 1930 (Ballston Lake, N. Y.).

The most common *Psocus* in Indiana; it is found on trunks of deciduous trees.

Records—Dunes St. Pk. VIII/15/50 2 ♀. Indpls. '44: VII/5 & 14 ♀ 2 N; '45: VII/9-VIII/7 3 ♂ 6 ♀ 8 N, VII/20 (light) ♂; '47: VII/29

3 ♀ 11 N, X/20 (light) ♀. Shelby VIII/15/47 ♀ 10 N. Winona Lake '47: VIII/2 & 5 (light trap) 2 ♂, VIII/11 3 ♀.

56. Psocus variabilis Aaron

Psocus variabilis Aaron. Trans. Am. Ent. Soc. 11:38, 1883 (Philadelphia Penn.).

Records—Bloomington IX/23/49 (deciduous branches) 2 ♀.

FAMILY MYOPSOCIDAE

57. Lichenomima sparsa (Hagen)

Psocus sparsus Hagen. Syn. Neur. N. A., p. 11, 1861.

Records—Bloomington IX/24/49 (limestone) 2 ♀. Winona Lake VIII/4/47 (silver maple trunk) 22 ♂ 8 ♀ 36 N.

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Notes and Records of Indiana Odonata, 1941-1950

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In 1917 Williamson (5) published "An annotated list of the Odonata of Indiana"; this paper listed 125 species and gave the records for the state, by counties and thirds of months, for each species. In 1921 he published additional records, including one of a species not previously known from the state.

The author has published a series of "Records of Indiana Dragonflies" (1925-1941), summarizing the field observations and collections from 1920 to 1940 inclusive. An additional 15 species were added to the state list in these papers (2). Scott studied the Odonata of the Tippecanoe River State Park in Pulaski County during the summers of 1943-1945 and published an annotated local list (4) of 59 species.

The author has also published a series (1942-1948) of papers on the distribution and relative seasonal abundance of the Indiana species of Odonata based upon the 1900-1940 records. In these papers (3) the seasonal range for each species is shown in a time-frequency graph based upon the frequency of collection or observation in each third of a month.

The author has collected or received from other collectors 6590 specimens of Odonata taken in Indiana during the period of 1941 to 1950 inclusive. The observations and records of these collections, which include 103 species, increase our knowledge of the dragonfly fauna of Indiana considerably. Three species not previously known from the state are included; these additions bring the state list of Odonata to 144 species.

Records extending the seasonal range of any species (from that given in the 1942-1948 studies), counties in which any species has been found for the first time, records of rare species and new or unusual observations of other species are given in the following list. The numbers of Williamson's 1917 list and the later interpolations are followed. Species recorded from Indiana for the first time are starred (*).

3. *Calopteryx maculatum* (Beauvois). Benton.

5. *Hetaerina titia* (Drury). Gibson.

6. *Lestes congener* Hagen. Tippecanoe.

7. *L. disjunctus* Selys. Cass, Jefferson, Randolph, Tippecanoe, Warren.

9. *L. forcipatus* Rambur. Tippecanoe.

10. *L. inaequalis* Walsh. Clark. This species was fairly common at Schlamm Lake in the Clark County State Forest during June of both 1949 and 1950, and a male and a female were taken August 12, 1950, although it had never been noted in this area before. Only one male was taken at nearby Francke Lake—in June, 1949. The August

record extends the season of this species as the latest previous record was in mid-July.

11. *L. rectangularis* (Say). Clark, Fountain, Lawrence, Marion, Randolph, Tippecanoe, White. New early records: 2 ♂ 3 ♀, May 29, 1942, 4 ♂ 2 ♀, May 30, 1946, pools, near Oakland City.

12. *L. dryas* Kirby. Carroll, Fountain, Tippecanoe, Warren.

13. *L. unguiculatus* Hagen. Carroll, Marion, Warren. New late records: Oct. 3 (3 ♂) and 10 (1 ♀), 1943, Hadley's Lake, Tippecanoe County.

14. *L. vigilax* Hagen. Cass.

16. *Argia moesta* (Hagen). Knox, Warren.

17. *A. sedula* (Hagen). Gibson.

18. *A. tibialis* (Rambur). Carroll, Johnson. New late records: 5 ♂ 6 ♀, Sept. 20, 1942, Patoka River, near Princeton; 2 ♂, Oct. 7, 1943, lake, Boonville.

19. *A. translata* Hagen. Marion. A female of this species was taken at the Riverside Fish Hatchery, August 15, 1948; the only previous record for the state was based on four males collected at St. Paul, Shelby County, in August, 1911. *A. translata* has a wide distribution, ranging from Connecticut and North Carolina through the Ohio Valley, Oklahoma, Texas, Mexico and Central America to Venezuela.

20. *A. violacea* (Hagen). Benton, Putnam.

21. *Enallagma antennatum* (Say). Benton, Cass.

22a. *E. basidens* Calvert. Cass, Fountain, Parke, Posey, Randolph, Tippecanoe, White. New late record: 3 ♂, Oct. 7, 1943, lake, Boonville.

24. *E. carunculatum* Morse. Cass.

25. *E. civile* (Hagen). Putnam, Warren.

27. *E. divagans* Selys. Clark.

29. *E. exsulans* (Hagen). Benton.

30. *E. geminatum* Kellicott. Cass.

33. *E. vesperum* Calvert. Blackford.

34. *E. signatum* (Hagen). Warren.

35. *E. traviatum* Selys. Cass.

*35a. **Teleallagma daeckii* (Calvert). This species has been known previously only from the Atlantic coastal area—New Jersey, Maryland, the Carolinas and Florida. The species was recognized as new to the state when individuals were found among vegetation that was in deep shade and still wet with dew, along the margin of Schlamm Lake, about nine o'clock in the morning of June 25, 1949. Thorough search at this time yielded five males and one female, but no additional specimens were taken in extensive collecting later in the day. Seven males and one female were taken between eight and nine o'clock the following morning at the same locality. All of these were found in a very limited area, around shrubs growing in the edge of the water near the dam at the lower end of the lake. When disturbed these insects flew into the shrubs or other vegetation. In June, 1950, this species was relatively common along the lake margin for some distance from either

end of the dam and specimens could be taken at any time during the day; 50 males and 33 females were collected. A female of this species, not recognized when collected, was found in the collection from Schlamm Lake, June 28, 1947.

37. *Nehalennia irene* Hagen. LaPorte, Tippecanoe.

37a. *Amphiagrion abbreviatum* (Selys). Benton.

38. *A. saucium* (Burmeister). Carroll.

41. *Ischnura posita* (Hagen). Blackford, Benton. New late records: Sept. 26 (1 ♂), Oct. 3 (2 ♂), Oct. 10 (1 ♂ 1 ♀), 1943, Oct. 29 (1 ♂), 1950, Hadley's Lake; 2 ♂ 3 ♀, Oct. 7, 1943, lake, Boonville. These records extend the season for this species a month as the latest previous records were for the last third of September.

43. *I. verticalis* (Say). Putnam.

44. *Anomalagrion hastatum* (Say). Carroll, Marion, Warrick, White.

45. *Tachopteryx thoreyi* (Hagen). Males of this species were collected along the Tippecanoe River, near Springboro, Carroll County, in the vicinity of a boggy area, June 21 and July 5, 1941.

*46a. **Cordulegaster erroneus* Hagen. A male of this species, collected along the Tippecanoe River, Tippecanoe County, June 7, 1947, was given me by a student. The known distribution of *erroneus* is discontinuous, including an eastern area extending from Ohio and Connecticut to Florida and a western region in Washington, Nevada and California, with no records for the territory between the two.

49. *Progomphus obscurus* (Rambur). Benton, Carroll, Tippecanoe.

50. *Hagenius brevistylus* Selys. Crawford, Carroll.

52. *Erpetogomphus designatus* Hagen. Tippecanoe, Warren. New early records: 2 ♂ 6 ♀, June 11, 1941, gravel pit, Emison; 1 ♀ each—June 14, 1941, Wabash River, opposite Covington, and June 15 & 22, 1942, near West Lafayette; the earliest previous record was mid-July.

52a. *Gomphus amnicola* Walsh. Fourteen males and nine females of this rare species were taken from 1941 to 1945 along the Wabash River in Tippecanoe and Warren counties. New early record: 4 ♂ 5 ♀, June 14, 1941, Wabash River, opposite Covington.

55a. *G. externus* Hagen. Carroll, Fountain, Knox, Vermillion. New seasonal records: 1 ♂, May 29, 1941, in greenhouse, West Lafayette; 1 ♀, Aug. 4, 1946, Patoka River, near Princeton. The previously known seasonal range of this species in Indiana included the last two thirds of June and the first and last thirds of July.

56. *G. fraternus* Say. Benton, Carroll.

58. *G. graslinellus* Walsh. Clark.

59. *G. lividus* Selys. Starke.

59a. *G. notatus* Rambur. Tippecanoe.

59b. *G. plagiatus* Selys. New late record: 1 ♂ 1 ♀, Sept. 20, 1942, Patoka River, near Princeton.

60. *G. quadricolor* Walsh. Carroll.

62. *G. spiniceps* Walsh. Tippecanoe, 1 ♂, Aug. 11, 1941, near Tippecanoe River—new late record.

62a. *G. lentulus* Needham. Knox County, pond, 1 ♂, Aug. 15, 1939. The few previous records of this species in Indiana have been in mid-July. Mrs. Gloyd (1941) has shown that Williamson's *subapicalis*, the name under which this species has been reported from Indiana previously is a synonym of *lentulus* Needham.

63. *G. submedianus* Williamson. New early record: 4 ♂ 1 ♀, May 30, 1942, Foote's Lake, Gibson County.

64. *G. vastus* Walsh. Carroll, Vanderburg.

65. *G. ventricosus* Walsh. Carroll, Warren.

66. *G. villosipes* Selys. Clark.

68. *Dromogomphus spinosus* Selys. Clark.

69. *D. spoliatus* (Hagen). New early records: June 9 (1 ♂ 1 ♀), 12 (1 ♂, 1941, 1 ♀, June 25, 1949, 1 ♂, June 26, 1950, lakes, Clark County State Forest.

72. *Anax junius* (Drury). Clark, Marion.

75. *Aeshna constricta* Say. Posey.

78. *A. umbrosa* Walker. Carroll. New late record: 1 ♂, Oct. 21, 1947, Burnett's Creek, Tippecanoe County.

81. *Epiaeschna heros* (Fabricius). Knox, Monroe.

83. *Macromia illinoiensis* Walsh. Carroll, Fountain.

84. *M. pacifica* Hagen. Tippecanoe. A male of this species, taken "hawking along a tree-bordered road" near the Tippecanoe River, July 4, 1949, is the first record of this species in the state in almost 20 years.

87. *Epicordulia princeps* (Hagen). Tippecanoe.

89. *Tetragoneuria cynosura* (Say). Blackford, Carroll, Greene, Marion, Noble, Warrick, White. New early record: 1 ♀, wheat field, White County, June 8, 1945.

93. *Somatochlora ensigera* Martin. Tippecanoe, 1 ♂, July 4, 1949. This specimen was taken along an old farm road, between a fence and a row of trees and shrubs, about 1/4 mile from Hadley's Lake. Only a few other dragonflies—*Plathemis lydia*, *Libellula luctuosa*, *Erythemis simplicicollis* and *Ischnura verticalis*—were fluttering about.

98. *Libellula incesta* Hagen. Clark.

99. *L. luctuosa* Burmeister. Benton, Cass, Porter, Posey, Putnam.

102. *L. semifasciata* Burmeister. Putnam.

103. *L. vibrans* Fabricius. Clark, five specimens were taken in the State Forest—1 ♀, June 26, 1950, Francke Lake; streams, 1 ♂, June 26, 1948, 3 ♂, June 24, 1950. All the males were found at points where the course of the stream made a sharp turn in a "semi-open" space in the forest.

104. *Plathemis lydia* (Drury). Benton, Putnam.

105. *Perithemis tenera* (Say). Putnam, Tippecanoe. New early records: 1 ♂, May 30, 1942, Foote's Lake; 1 ♂, June 9, 1941, Schlamm Lake.

107. *Erythemis simplicicollis* (Say). Cass, Posey.

108. *Sympetrum ambiguum* (Rambur). Lawrence, Tippecanoe. New seasonal records: 2 ♂, May 30, 1946, gravel pit, West Lafayette; 1 ♂ 1 ♀, Oct. 1, 1944, Hadley's Lake.

110. *S. internum* Montgomery. This species, long known as *decisum,* has always been very rare in Indiana, although Walker has recorded it frequently throughout Canada. However, in 1943 it "exploded" into great abundance at two ponds in Tippecanoe County and, probably, throughout a large area for which we have no records. Collections have been made over a period of several years at Hadley's Lake, a body of water about three miles northwest of West Lafayette. This lake has a considerable area but is frequently reduced to a few pools of stagnant water and extensive mud flats, in the late summer. On September 23, 1940, a few specimens of *Sympetrum* were obtained here, and when the specific determinations were made the following winter the collection was found to consist of *S. internum*—2 ♂, *S. obtrusum*—5 ♂, and *S. rubicundulum*—20 ♂ 2 ♀. In spite of the interest in the appearance of this species, no visit could be made to Hadley's Lake in 1941 and only one in 1942, on September 13, when the only specimens of *Sympetrum* obtained were a male and a female each of *rubicundulum* and *vicinum.* Four visits were made in each of the following years—1943 and 1944—and because of the abundance of *Sympetrum* extensive collections were made to determine the proportion of the different species present. In 1943 *internum* was by far the most abundant species of the genus, but in 1944 *obtrusum* was the most abundant and *rubicundulum* was as common as *internum.*

	1943				1944		
	Sept. 26	Oct. 3	Oct. 10	Oct. 20	Sept. 10	Sept. 24	Oct. 1
ambiguum					1♂	1♀	1♂ 1♀
internum	72♂	110♂	67♂		13♂	8♂	14♂
obtrusum	15♂	18♂	21♂	1♂	94♂	45♂	38♂
rubicundulum	5♂	10♂ 3♀	3♂		19♂ 4♀	6♂	9♂ 2♀
vicinum	1♂ 1♀	1♀	3♀				

No dragonflies were seen on October 18, 1944

Visits to the same locality since 1944 have been infrequent and very few specimens of *Sympetrum* have been found: Oct. 21, 1947, *obtrusum*—3 ♂; Oct. 7, 1945, *vicinum*—2 ♂; July 4, 1949, *rubicundulum*—1 ♀; Oct. 29, 1950, no dragonflies of this genus. At ponds several miles east of Hadley's Lake, collections of *Sympetrum* were made in August and September, 1943, and *internum* was the most abundant species in the September collections. In collections on August 15, 21 and 22, only *rubicundulum* was found—2 ♂, 2 ♂, and 4 ♂ 2 ♀, respectively; on September 28 and 30 the collections included *internum*—39 ♂ and 44 ♂, *obtrusum*—1 ♂ and 5 ♂, *rubicundulum*—6 ♂ and 4 ♀ 1 ♀, and *vicinum*—2 ♂ 2 ♀ and 1 ♂ 4 ♀.

A collection from a pond at Stewartsville, Posey County, Oct. 5, 1943, included 1 ♂ each of *internum* and *rubicundulum* and 4 ♂ 2 ♀ of *vicinum.*

All previous records of *internum* in Indiana were in the middle third of September.

111. *S. obtrusum* (Hagen). Fountain. New late records: Oct. 20, 1943 and Oct. 21, 1947, Hadley's Lake, as listed in the discussion of *S. internum* above.

112. *S. rubicundulum* (Say). Carroll, DeKalb, Fountain, Porter, Posey, Randolph.

113. *S. semicinctum* (Say). Cass.

114. *S. vicinum* (Hagen). Carroll, Posey, Putnam, Warrick.

115. *Pachydiplax longipennis* (Burmeister). Cass, Clay, Porter, Putnam, Warren, White.

118. *Celithemis elisa* (Hagen). Cass, Knox. New late records: 3 ♂, Sept. 19, 1942, and 1 ♂, Oct. 7, 1943, lake, Boonville.

119. *C. eponina* (Drury). Cass, Clark, Tippecanoe. New late records: 6 ♂, Sept. 19, 1942, and 1 ♂, Oct. 7, 1943, lake, Boonville.

119a. *C. fasciata* Kirby. This species was added to the state list in 1937 on the record of a specimen from a lake at Oakland City and the species was found to be well established there later. In 1946 two males were captured in the Clark County State Forest and the species has since become rather common at Francke and Schlamm lakes in the forest. The specimens from this area show considerable variation and tend to be intermediate between *C. monomelaena* from northern Indiana and Michigan and *C. fasciata* from the southern states. The Oakland City records were in mid-June and mid-July; 3 ♂ 1 ♀ were taken at the Clark County lakes, August 11, 1950.

120. *C. monomelaena* Williamson. Cass.

*120a. **C. verna* Pritchard. This species has been known previously only from North Carolina, Georgia and Oklahoma. It was found at Schlamm Lake in both 1949 and 1950—1 ♂, June 25 and 1 ♀, June 26, 1949; 1 ♂, June 24, 1950.

123. *Tramea carolina* (Linné). Warrick.

124. *T. lacerata* Hagen. Greene, Putnam.

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The Effects of Some of the Newer Insecticides on Tomatoes and Tomato Insects[1]

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The development of new insecticides has proceeded at a rapid rate since World War II. Although these new toxicants may become of tremendous value in the field of economic entomology, their possibilities have not always been fully investigated prior to their release for general use.

An evaluation of some new materials on the tomato plant was undertaken because certain insects are a serious problem on this major Indiana vegetable crop. In addition, the tomato plant is recognized as being sensitive to many materials. From this investigation, it was hoped to establish the value of these new materials in the control of the insect pests on tomatoes.

Six new materials were tested as dusts and as sprays. These were DDT, TDE, chlordane, parathion, toxaphene and methoxychlor. With the exception of parathion these materials were used in sprays as wettable powder suspensions and as emulsions. In the spraying experiments lead arsenate was used as a standard control for comparison, while in dusting a 3/4 per cent rotenone mixture was the standard. Two additional materials, ditolyl trichloroethane (Gytol from Geigy) and purified or aerosol grade DDT (DuPont), were included with the dusts formulations.

Methods and Equipment

The experiments reported herein were carried out on the Murtaugh farm near Lafayette, Indiana, in the summer of 1948. Three plantings of tomatoes used in the experiments were made on May 3, May 18 and June 9. The seeds were drilled with a single row Planet Junior garden seed drill. The rows were spaced 42" apart to permit tractor cultivation. The plots were laid out in a randomized block design and replicated. The rows were interspaced with rows of beans to help prevent the drift of sprays and dusts from one plot to another. The insecticides were applied as dusts to the first two plantings and as sprays to the third planting. Records of injury, fresh weight, and heights of plants were made and the number and weight of ripe fruit harvested and the weight and number of green fruits left at the first killing frost recorded. Records of the effects of the insecticides on the potato aphid were made on the third planting.

The dust concentrations for the first two plantings, except for parathion, were mixed in a Day Sifter and Mixer, using pyrophyllite

[1] This paper is based on a Master's Thesis submitted at Purdue University, in June, 1949.

(Pyrax ABB) as a diluent. The parathion dusts, .25 per cent and 1.0 per cent, were the commercial products of the American Cyanamid Company. The dusts were applied with a Hudson Hand Duster No. 766 such as is commonly used by home gardeners. The sprays were mixed in the field and applied with a Hudson knapsack sprayer, Dumore, which has an agitator.

Records of the injury to the plants from spraying or dusting the tomato seedlings were made as soon as sufficient visible injury had developed, usually in 48 hours. The injury was given a numerical rating from 0 to 10, 0 indicating no visible injury and 10 indicating a dead plant.

The fresh weight samples on all plantings were made by selecting ten plants at random from each plot. The ten plants selected were cut off at ground level and placed in a one quart waxed ice cream carton for transportation to the laboratory. Although the weighings were made as soon as possible, it was thought that this technique of temporary storage and transportation would prevent severe moisture loss. A rapid estimate of the height of the ten plants on the second and third plantings was made by laying the ten plants on a lined chart and striking a visual average.

The aphid counts taken on the third planting were made by choosing ten leaves at random from each plot. The leaves selected were the fourth or fifth from the top of the growing tip. The leaves were carefully turned over and the aphids, nymphs and adults counted.

The ripe tomatoes were picked every other day and weighed on a spring scale suspended from a tripod. The weight and the number picked from each plot were recorded for each picking. After the first killing frost the green fruits remaining on the vines were picked, counted, weighed, and recorded.

Experiments

First Planting. On May 29 the first application of dusts was made when the tomatoes were just forming their third true leaf. Readings of the injury caused by this dust application were made on June 1. A second application of dusts was applied on June 8, and three days later the resultant injury was recorded. On June 14 the first fresh weight samples were taken. This sample was followed the next day by a second sample of fresh weights.

On the basis of total weight of the two samples (Table I) rotenone 3/4 per cent was the only treatment statistically heavier than the untreated check. All other insecticide treatments were significantly lighter than the untreated check. The chlordane treatments were significantly lighter and more stunted than all other treatments and the check. Chlordane 5 per cent was significantly lighter than the 1 per cent chlordane. All other treatments were significantly better than chlordane, and significantly worse than parathion .25 per cent, DDT 1 per cent, TDE 5 per cent, rotenone 3/4 per cent, and the untreated check. There was no significant difference in the weights of the parathion 1 per cent and the DDT 5 per cent plots.

TABLE I. Results Obtained from Two Applications of Dusts to the First Planting of Indiana Baltimore Tomatoes, planted May 3.

Chemical	Per cent Concentration	Fresh Weights in Grams			Numerical Rating of Injury*		Visible Injury
		6/14	6/15	Grand Total			
Rotenone	3/4	572.5	759.5	1332.0	0	0	Non-visible
Check	untreated	598.5	617.5	1216.0	0	0	Non-visible
Parathion	1/4	464.1	595.0	1059.1	0	0	Non-visible
DDT	1	457.0	558.5	1015.5	9	1	Chlorosis
TDE	5	475.6	526.5	1002.1	11	10	Chlorosis
Parathion	1	474.5	495.5	970.0	0	0	Non-visible
DDT	5	413.5	550.5	964.0	9	12	Chlorosis
TDE	1	442.1	491.5	933.6	3	1	Chlorosis
Chlordane	1	415.0	439.0	854.0	12	19	Chlorosis
Chlordane	5	293.0	416.5	709.5	26	34	Chlorosis
L.R.D. 0.05	Significance	17.86	20.24	8.70	15.06	.471	
L.R.D. 0.01		—	—	—	17.41	.544	

*Maximum number of points possible—60.

DDT, TDE, and chlordane, at the strengths tested, caused chlorosis of the leaflets. The chlorosis took place at nearly any spot on the surface of the leaf, and was especially noticeable in areas where the dust became concentrated a little too heavily. Parathion dusts, .25 and 1.0 per cent, caused no visible injury such as burning or chlorosis but the data revealed stunting.

A few scattered insects were observed on the first planting, but none became abundant enough to be noticeable.

Second Planting. The second planting was dusted with two dilutions of aerosol grade DDT, two dilutions of ditolyl analogue of DDT and 5 per cent concentrations of technical grade DDT and TDE. On June 16 the first series of dusts was applied to the second planting. Seventy-two hours later, on June 19, the first injury reading was made. As shown in Table II, DDT and TDE caused light injury which took the characteristic form of chlorosis as noted on the first planting.

Eight days after the first dusting, a second application was made. A total of 1.06 inches of rain fell in two heavy showers before the injury readings could be made seventy-two hours later. The results of this reading, as shown in Table II, was light injury caused by the 5 per cent DDT, and moderate injury caused by TDE. The injury was in the form of yellowing of the younger leaves with a slight amount of actual burning in a few cases.

On July 1, fifteen days after the first application of dusts and nine days after the second dusting, the first fresh weight samples of the second planting were taken. A total of 3.04 inches of rain fell between the first dusting and this fresh weight sample. Both height measurements in inches and weight in grams were taken.

Statistical treatment of the data showed neither height nor weight measurements to be significant, although the height measurements approached significance. The check plants, untreated, were taller than any

TABLE II. Results of Dusting the Second Planting of Tomatoes

Chemical	Total Fresh Weights	Total Height	Numerical Rating of Injury*		Visible Injury
DDT Aerosol Grade 5%	1147.0	64.0	0	0	Non-visible
GyTol DDT 5%	1122.0	63.5	0	0	Non-visible
DDT Aerosol Grade 1%	1017.5	63.5	0	0	Non-visible
Check—untreated	997.5	65.5	0	0	None
DDT Technical Grade 5%	843.5	57.0	6	12	Chlorosis
GyTol DDT 1%	839.0	58.0	0	0	Non-visible
TDE Technical Grade 5%	782.5	55.5	7	28	Chlorosis
L.R.D. 0.01	——	——	——		.378
L.R.D. 0.05	——	——	——		.438

*Maximum number of points possible—50.

of the dust treated plants, although not significantly so. GyTol 1 per cent, DDT technical and TDE technical apparently caused dwarfing. On the basis of weight, the 5 per cent dusts of GyTol and Aerosol grades of DDT appeared to stimulate seedling growth. The other treatments and concentrations caused injury reflected as stunting, although the differences were not significant and merely indicated a trend. The results of this experiment are presented in Table II.

Several species of insects were noted on the second planting but none became abundant enough to be noticeable.

Third Planting. The plots of the third planting of tomatoes were sprayed with wettable powder suspensions and emulsions for the first time on July 3 at the dilutions shown in Table III. The plants were sprayed a total of five times and in the fourth application (August 12) a fungicide, Dithane Z-78, was combined with each of the insecticides as a disease preventative. The check plots were treated with the fungicide only. It was noted that methoxychlor and Dithane Z-78 were incompatible and formed a gummy precipitate.

TABLE III. Dilutions of Sprays for the Third Planting of Indiana Baltimore Tomatoes

Chemical	Formulation	Dilutions per 100 gallons of water	Dilutions per 2 gallons of water
DDT	50% Wettable	2.0 pounds	18.1 gm.
DDT	25% Emulsion	1.0 quart	19.0 cc
TDE	50% Wettable	2.0 pounds	18.1 gm.
TDE	25% Emulsion	1.0 quart	19.0 cc
Methoxychlor	50% Wettable	2.0 pounds	18.1 gm.
Methoxychlor	25% Emulsion	1.0 quart	19.0 cc
Arsenate of Lead		4.0 pounds	36.2 gm.
Chlordane	40% Wettable	2.5 pounds	22.6 gm.
Chlordane	25% Emulsion	1.0 quart	19.0 cc
Toxaphene	40% Wettable	2.5 pounds	22.6 gm.
Toxaphene	40% Emulsion	0.5 quart	9.5 cc
Parathion	25% Wettable	2.0 pounds	18.1 gm.
Check—untreated			

Readings of the injury was made as soon as the injury developed enough to be readily visible. This was usually in about three days. Two weight samples and height measurements were taken in the manner described under Methods and Equipment. Then the plants were thinned to eight per plot on July 26 and their height measured.

At the time of the first injury reading the plants were just forming their first true leaves and varied in height from approximately one to three inches. Light injury was noted on DDT wettable and DDT emulsion, TDE wettable, and methoxychlor emulsion plots. These in-

TABLE IV. Height, Weight, and Injury Data for the Third Planting.

Chemical	Fresh Weight (10 plants)		Height Total (10 plants)			(Max. 50) Numerical Rating of Injury			Visible Injury
	7/19	7/26	7/19	7/26	7/28				
Chlordane W	758.5	1360.5	29.0	45.5	62.0	0	1	0	Chlorosis
Toxaphene E	702.5	1525.0	27.0	45.5	66.0	0	0	0	None
TDE W	683.0	1182.5	25.0	40.5	57.0	2	6	5	Chlorosis
TDE E	659.5	1304.5	24.5	45.0	60.5	0	5	0	Chlorosis
Toxaphene W	642.5	1392.5	26.0	45.0	62.5	0	0	0	None
Methoxychlor E	589.0	1092.5	25.0	40.5	63.5	4	7	0	Chlorosis
Methoxychlor W	561.5	1448.5	25.0	42.0	64.5	0	1	5	Chlorosis
Chlordane E	546.5	1455.0	24.5	41.5	60.0	0	0	0	None
Parathion W	546.5	878.5	25.5	37.5	56.0	9	14	21	Burning
Arsenate of Lead	520.5	1205.0	26.0	40.0	60.5	0	0	0	None
DDT E	512.5	1089.5	23.5	40.5	56.0	5	0	0	Chlorosis
Check	471.0	1121.5	25.5	39.0	54.0	0	0	0	None
DDT W	394.0	1006.0	24.0	37.5	53.5	3	8	5	Chlorosis
L.R.D. 0.05	28.30	—	—	—	—	.434	1.19	.202	
L.R.D. 0.01	32.68	—	—	—	—	.501	1.38	.283	

juries were in the form of yellow chlorosis of the new leaves. Parathion sprayed plots showed injury in the form of browning and actual burning of the leaves, particularly along the margins.

The injury from the second spray application was recorded five days after the application, since it was noted that the symptoms developed more slowly than with dust applications. There was .24 inch of rain between the date of application and the injury reading. Light chlorosis was noted on the DDT, TDE and methoxychlor plots. Rather heavy chlorosis was noted on the TDE wettable treated plants. As in the case of the previous spraying, parathion caused moderate injury of the leaves by actual burning.

Three days after the third spraying a third injury reading was made. DDT, TDE, and methoxychlor wettable powder applications all caused injury in the form of light chlorosis and parathion caused moderate injury by burning.

No chlorotic injury was noted as a result of the fourth and fifth sprays. The DDT plots, however, showed symptoms of injury reflected as small, linear leaves, which showed a tendency to spiral and twist like the hormone-growth effect of 2,4-D.

On July 19 the first fresh weight sample was taken. On the basis of the weight of the plants as shown in Table IV, the DDT wettable plots were significantly lighter than the untreated check and all other treatments. Both wettable and emulsion forms of TDE, methoxychlor, and toxaphene were statistically superior to the standard control, lead arsenate. Of the chlordane formulations, only the wettable powder was superior to the standard control. Both DDT formulations were statistically inferior to the lead arsenate treatment.

One week after the first weight sample was taken, a second sample was taken. Statistical examination revealed that differences in height and weight were not significant. The parathion plots, however, were lighter and both the parathion and DDT wettable plots were shorter.

The first ripe fruits picked were from the chlordane formulation plots. This was on September 13, and four days later all treatments yielded a few fruits. All yield data are presented in Table V. There was no correlation between the weights of green and ripe fruits.

On the basis of the yield of ripe fruits, methoxychlor wettable, chlordane emulsion, and toxaphene emulsion showed no significant differences. These three treatments yielded a significantly larger number of ripe fruits than all other treatments and the untreated check. There was no significant difference in the number of tomatoes yielded by lead arsenate and chlordane wettable, but both of these treatments significantly outyielded both TDE formulations, methoxychlor emulsion, both DDT formulations, the untreated check, toxaphene wettable, and parathion wettable treated tomatoes. There was no significant difference in the yields of the TDE formulations, but this material was significantly superior to methoxychlor emulsion, DDT formulations, the untreated check, toxaphene wettable, and parathion wettable plots. The yield of ripe tomatoes from the DDT emulsion plots was significantly

TABLE V. Yield Data of Third Planting, Ripe and Green Tomatoes.

Chemical	Ripe			Green				
	Number	Total Weight Lbs.	Average Weight per Fruit Lbs.	Number	Total Weight Lbs.	Average Weight per Fruit Lbs.	Grand Total Weight	Grand Total Weight
DMDT W	389	158.2	.407	1765	433.5	.244	591.7	2154
Chlordane E	389	155.4	.399	1555	337.9	.217	493.3	1944
Toxaphene E	381	145.4	.379	1747	371.9	.212	517.3	2128
Chlordane W	367	142.4	.388	1234	298.2	.241	440.6	1601
Arsenate of Lead	356	145.6	.408	1750	417.6	.238	563.2	2106
TDE W	341	145.2	.425	1573	383.1	.243	528.3	1914
TDE E	329	130.4	.396	1490	325.2	.245	455.6	1819
DMDT E	305	119.0	.389	1682	399.0	.237	518.0	1987
DDT E	301	123.6	.410	1797	436.3	.245	559.9	2098
Check	297	118.4	.398	1341	334.3	.249	452.7	1638
Toxaphene W.	280	110.8	.395	1390	315.9	.227	426.7	1670
DDT W	259	93.5	.361	1741	382.6	.219	476.1	2000
Parathion W	251	104.1	.414	1725	414.9	.240	519.0	1976
L.R.D. 0.05	13.76	——	——	76.10	10.94	----	13.55	----
L.R.D. 0.01	——	——	——	——	12.64	----	----	----

better than that from the DDT wettable plots. Toxaphene wettable, DDT wettable, and parathion wettable plots were all inferior in their yields to that of the untreated check.

Statistical examinations of the data on the basis of the weight per fruit showed that the data were not significant. TDE wettable plots showed the largest average weight per fruit, closely followed by parathion wettable, DDT emulsion, arsenate of lead, methoxychlor wettable, chlordane emulsion and the untreated check. The average weights of TDE emulsion, toxaphene wettable, methoxychlor emulsion, chlordane wettable, toxaphene emulsion, and DDT wettable were all smaller than the untreated check. DDT ripe fruits averaged less per fruit than any other treatment.

On the basis of the number of green fruits left on the vine at the killing frost, October 18, it was found that there was no statistical difference in the plots treated with DDT emulsion, methoxychlor wettable, arsenate of lead, toxaphene emulsion, DDT wettable, or parathion wettable, but all of the above treatments left significantly higher numbers of fruits on the vines than methoxychlor emulsion, the TDE formulations, the chlordane formulations, toxaphene wettable, and the untreated check. Chlordane wettable had significantly less fruit left on the vine at frost than did the untreated check. On the basis of this result, it would appear that chlordane wettable did not delay maturity.

DDT emulsion and methoxychlor wettable showed no significant difference in the weight of the green fruits left on the vine at frost, but their weights were highly significantly heavier than all remaining treatments. The differences between the weights of the fruits left on the vines of the untreated check and the TDE emulsion plots were not significant, but the weight of the green fruits left on the toxaphene wettable and chlordane wettable plots were significantly smaller than that of the untreated check and all other treatments but TDE emulsion. It would appear that DDT emulsion, methoxychlor wettable, arsenate of lead, parathion wettable, methoxychlor emulsion, TDE wettable, DDT wettable and toxaphene emulsion all delayed the maturity of Indiana Baltimore tomatoes under the conditions of this test.

There was no statistically significant difference in the average weight per fruit of the green fruits left on the vine at frost, but the fruits from all treatments were smaller than those from the untreated check.

On the basis of total weight yielded, including ripe and green fruits, the yield from methoxychlor treated plants was significantly higher than that from all other treatments. Toxaphene wettable treated plants were the only ones significantly lighter in yield than the untreated check, although chlordane wettable treated plots were lighter and nearly significantly so. On the basis of these results, it would appear that chlordane wettable and toxaphene wettable reduced the crop yield.

The plants treated with chlordane formulations had the highest percentage of their crop ripe by frost. The chlordane treated plants were closely followed by the TDE formulations, toxaphene emulsion,

methoxychlor wettable treated plants, and the untreated check. Evidently these treatments stimulated maturity. Lead arsenate, toxaphene wettable, methoxychlor emulsion, DDT formulations and parathion wettable, apparently delayed maturity of fruits as they had a smaller percentage of ripe fruit than did the untreated check.

By August 12 colonies of aphids were building up in sufficient numbers to give reliable data. Four aphid counts were made as shown in Table VI. The data obtained by the first three aphid counts showed significant differences while those from the fourth count were not significant.

TABLE VI. Results of Four Samples of the Potato Aphid Population on the Third Planting of Indiana Baltimore Tomatoes.

Chemical	Aphid Population			
	Sample 1 August 21	Sample 2 September 7	Sample 3 September 13	Sample 4 September 21
Toxaphene W	593	998	1172	1877
Chlordane W	576	2040	2283	2730
Methoxychlor W	569	1082	1001	1579
Chlordane E	517	763	1519	2403
TDE W	490	820	1138	1918
DDT W	465	874	950	1873
TDE E	415	833	888	1468
Check—untreated	410	1619	2115	2266
Toxaphene E	406	242	309	1015
DDT E	346	111	338	882
Methoxychlor E	329	692	1348	2125
Arsenate of Lead	280	1452	1943	2691
Parathion W	65	4	51	59
L.R.D. 0.05	34.85	26.16	103.28	.
L.R.D. 0.01	.	30.20	119.26	

A comparison of the two types of formulations, wettable powder and emulsion showed that the differences in aphid abundance after treatment was not due to materials, but to the formulation. The emulsions were significantly better as aphicides than the wettable powders, except for methoxychlor where the reverse was true. The aphid populations on the chlordane wettable plots were much higher than the untreated check and in the first three samples was significantly so. Apparently chlordane stimulated the aphid populations. Parathion was the outstanding material, for it not only greatly reduced the initial population, but also kept it at a low level for several weeks.

Conclusions

All of the new insecticides tested as dusts injured tomato seedlings more than ¾ per cent rotenone dust. Rotenone and parathion were the only dusts which did not produce chlorosis of the seedlings. The five percent concentrations of the insecticides produced more chlorosis than the 1 per cent dusts. Both aerosol and technical grade DDT caused stunting of the seedlings, but the aerosol grade did not produce a visible chlorosis.

Applications of the new insecticides as sprays indicated that methoxychlor wettable powder was the best material when the four factors, visible injury, stunting, aphid control, and total yield of fruits were considered. Parathion was an outstanding aphicide, but as a spray caused serious burning and stunting of tomato plants.

The Status of Exotic European Corn Borer Parasites in Indiana

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Two years ago the author (1) reported on the introduction of exotic species of European corn borer parasites in Indiana. The following parasitic species, *Lydella grisescens*, *Macrocentrus gifuensis*, *Horogenes punctorius and Chelonus annulipes* which have been introduced in Indiana were discussed with particular reference to their habits. The results of the 1947 survey showing the establishment of *Lydella grisescens* were also tabulated.

Since then, in cooperation with the Bureau of Entomology and Plant Quarantine, annual fall surveys have been continued and were quite extensive, both in 1948 and 1949. In 1949 some counties in which

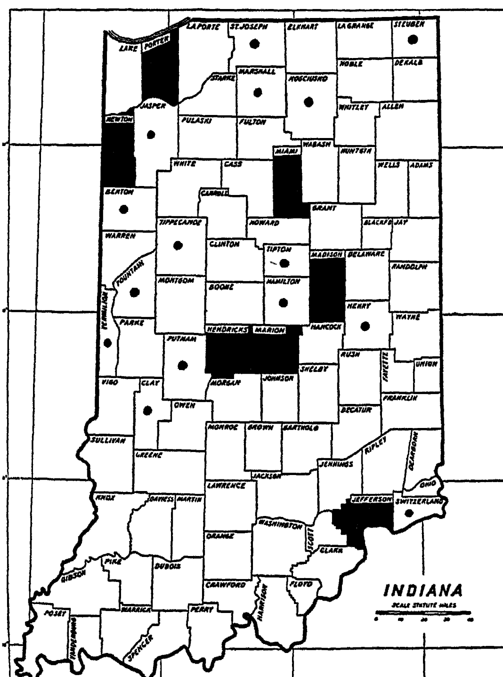

FIG. 1. Colonization and Dispersion of *Lydella stabulans grisescens* in Indiana. Black dots indicate counties where *L. grisescens* has been colonized. Blackened areas indicate counties where *L. grisescens* has never been released but to which it has dispersed.

parasites had never been released were surveyed to determine the spread of the parasites.

The extensive collections in Indiana in 1947, 1948 and 1949 provide a comprehensive picture of the status of exotic European corn borer parasites in the State (Fig. 1).

Lydella stabulans grisescens has not been released in Indiana since 1947. The recovery records for this species in each of the past six years are shown in Table I. It will be noted that where a release was made in Steuben County in 1929 and recoveries followed in 1929, 1930,

TABLE I. Parasitism by *Lydella stabulans grisescens* 1944-1949.

County	Percentage of Borers Parasitized					
	1944	1945	1946	1947	1948	1949
Benton	x	x	x	7.0*	x	18.6
Blackford	x	x*	x*	10.0	14.8	x
Clay	x	x	x	66.7*	27.8	x
Fountain	x	x	x	00.0*	x	x
Fayette	x	x	x	x	x	x
Hamilton	x	x	x	28.9*	15.8	20.7
Hendricks	x	x	x	0.0	1.1	19.2
Henry	x	x	x*	4.1*	4.7	8.8
Jasper	0.6*	6.0*	x	12.7	12.5	11.0
Jefferson	x	x	x	x	x	2.2
Kosciusko	x	x	x*	0.0	1.7	1.2
LaPorte	x	x	x	x	0.0	0.0
Madison	x	x	x	x	x	16.9
Marion	x	x	x	x	x	12.1
Marshall	x	x	x	0.0*	0.0	0.6
Miami	x	x	x	x	x	5.3
Newton	x	x	x	x	x	20.0
Porter	x	x	x	x	7.3	6.4
Putnam	x	x	x	0.0*	12.6	x
St. Joseph	0.0	x*	x*	6.8	11.6	1.2
Steuben	0.0***	x	x	x	3.6	1.3
Switzerland	x	x	x	0.0*	25.2	27.3
Tippecanoe	x	x	x*	x*	20.6	6.4
Tipton	4.5**	30.8*	35.5	30.0	26.7	14.6
Vermillion	x	x	x	15.5*	3.2	x

* Released here this year.

** Released here this year and in 1945.

*** Released here in 1929; recovered in 1929, 1930, 1933, and 1938; not recovered in 1931, 1932, and 1935.

x No collection made this year.

TABLE II. Recovery of Parasite Species by Townships in Steuben County, fall 1948, 1949.

wnship	Number of borers observed		Lydella grisescens				Horogenes punctorius				Eulophus viridulus				Macrocentrus gifuencis				Pyraustomyia penitalis*			
	1948	1949	1948		1949		1948		1949		1948		1949		1948		1949		1948		1949	
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
rk	x	31																				
ear Lake	195	43					20	10.3	3	7.0					1	0.5			1	0.5		
emont	x	40			1	2.5			2	5.0												
llgrove	x	30																				
easant	x	34			2	5.9			7	20.6												
chland	x	22							6	27.3												
sego	x	15																				
euben	x	25							1	4.0			1	4.0								

* A native parasite.
x Collections not made in 1948.

1933, and 1938 but not in 1931, 1932, 1935, and 1944, it was again recovered in 1948 and 1949.

After initial establishment was obtained in any other locality, *L. grisescens* was always recovered whenever a collection was made in a later year with the exception of Fountain County where it was not recovered in 1947 and 1948 and where collections were not made in 1949. This parasite is dispersing rapidly. Eight counties: Hendricks, Madison, Marion, Jefferson, Miami, Newton, LaPorte, and Porter where *L. grisescens* was never released were surveyed in 1949 and data show that this parasite has migrated to all of these counties with the exception of LaPorte from which no recoveries were obtained. This evidence of dispersion indicates that the parasite may now be rather widely spread in the State.

Horogenes punctorius was recovered from one of three collections taken in Steuben County in 1948 and from four of eight collections taken in 1949. It was released and recovered in York Township in this county in each of the three years, 1930, 1931, and 1932 but was not recovered from collections made in 1933, 1935, 1938 and 1944. The single collection which produced it in 1948 consisted of 92 borers of which 20 were parasitized. It was taken in Clear Lake Township, lying immediately north of York Township (Table II).

Attempts to colonize *Macrocentrus gifuencis* to date in Indiana appear to have been unsuccessful. Extensive releases have been made in 34 localities in the state, but only one borer, collected in Steuben County, has produced this species.

Eulophus viridulus was collected in three counties, Jasper, Kosciusko, and Vermillion in 1948 and Steuben in 1949.

From the data summarized in the tables it is evident that the colonization of *Lydella stabulans grisescens* has been successful. Its rapid dispersion is taking place and it is probably now quite general in many counties of Indiana. *Horogenes punctorius* and *Eulophus viridulus* have survived in a few localities but have not become abundant enough to be considered established. Colonization of *Macrocentrus gifuencis* is usually quite slow. However, although not evident in the surveys, enough of these may be surviving to eventually build up large populations as they have in southern New England.

Literature Cited

1. WILSON, M. CURTIS, 1949. The Introduction of Exotic Species of European Corn Borer Parasites in Indiana. Proc. Ind. Acad. of Sci. 1948, 58:157-159.

GEOLOGY AND GEOGRAPHY

Chairman: O. P. STARKEY, Indiana University

C. L. Bieber, DePauw University, was elected chairman for 1951.

ABSTRACTS

The flood problem in the watershed of the South Nation River (Ontario). R. LOUIS GENTILCORE, Indiana University.—The watershed of the South Nation River covers an area of approximately 1500 square miles in the eastern part of Ontario. The economy of the region is predominantly agricultural and centers around the Holstein cow and the cheese factory.

The most pressing problem that farmers here have to face is poor drainage. The South Nation River rises four miles north of the St. Lawrence and falls only 245 feet on its 100 mile course to the Ottawa. Because of the slight river gradient, approximately 55,000 acres flood every year. Floods reach serious proportions if there is a notable excess of spring precipitation. In the serious flood years of 1934, 1936 and 1938, March precipitation ranged from 25 percent to 90 percent in excess of normal.

The only solution proposed thus far for the problem is reforestation. Dams and reservoirs have also been suggested but due to the flatness of the land, good sites are difficult to find.

Ground water depletion in Ventura County, California. H. F. GREGOR, Indiana University.—Increasing irrigation, industrial and urban water demands, plus periodic droughts, have reduced ground water supplies in Ventura County to an all-time low. This situation is particularly serious in a coastal lowland located about fifty miles northwest of Los Angeles. One-third of all the lemons and commercial lima beans and one-tenth of the walnuts raised in the United States are produced in this section.

Excessive drafts have also encouraged salt water intrusion. By 1949 the hydraulic gradient was already sloping from the coast inland to a record depth of over fifty feet below sea level. Salt water has recently been noted in wells along the immediate coast. Prolongation of the present drought begun in 1943-44 and resulting increased irrigation demands are expected to intensify the situation—unless underground reservoirs are quickly recharged.

Surface reservoir construction in the adjacent mountains, as well as pumping of underground reservoirs farther inland so as to increase their capacity, have been proposed. Currently-wasted winter flood waters would then be trapped in both reservoirs and sent to

the deficit underground water areas of the lowland. Expense and opposition by ranchers in inland areas have prevented any progress beyond the planning stage, however.

Pioneer occupance of the Calumet region of Northwest Indiana-Northeast Illinois. ALFRED H. MEYER, Valparaiso University.—A cartographic representation and chorographic analysis of the occupance patterns of circulation, settlement, and industry of a region, as they have changed from time to time, are essential in understanding how the present-day landscapes have evolved out of the past.

This paper is one of four companion studies illustrating this type of sequent occupance treatment as applied to the Calumet region of Northwest Indiana-Northeast Illinois. It deals with the Pioneer stage of occupance.

Significant relationships of land and life are considered with reference to four primary geographic functions: Geographic position, regional differentiation, interregional relationships, and recognizable areal correlations between human and physical elements of the environment.

Fragmentation of the urban fringe in Indianapolis. BENJAMIN MOULTON, Butler University.—Urban growth in Indianapolis from the areal point of view has taken on two features that seem significant to the geographer. The first feature of growth has been eccentric and to the north and northeast from the center of the city. The second feature of growth, to which this paper is primarily directed, is the irregular and fragmented urban fringe. Fragmentation of this urban fringe can be traced from early days of the city as typical and has become more pronounced in recent years. The reasons for such fragmentation are related to both the natural and cultural environment but the natural elements appear to be the motivating forces underlying the cultural forces. Large expanses of relatively flat land is the key to the fragmentation of the urban fringe in Indianapolis.

Textile manufacture in eastern England: A study in industrial location. N. J. G. POUNDS, Indiana University.—The counties of Norfolk and Suffolk in England were the scene during the middle ages of a vigorous development of the woolen cloth industry which continued of importance until the end of the 18th century. The area formerly important for cloth manufacture is now the seat of a number of industries, including silk weaving and the manufacture of canvas and sailcloth, which have something in common with the earlier woolen industry.

The decline of the woolen industry, which was on a domestic basis, was in large measure due to the growth of the factory industry in the north of England. But its decline left a labor force in eastern England able and willing to accept work at lower wage levels than prevailed in London and elsewhere. At this time the silk industry, then established in London, was faced with rising wages in the capital, and employers turned to eastern England as an area in which to relocate their industry.

The silk and other textile manufactures came to this region to fill the economic vacuum left by the woolen industry.

The forces which build mountains. JAMES A. REEVES, Terre Haute.—The purpose of this paper is to analyze the forces which acted on the earth's crust since its creation. The two major forces being the attraction of the sun and the moon.

Engineering methods are applied to the problems of Geology.

Due to tilting axis of rotation, angularity of orbits, elliptical orbits, and other factors that produce small shiftings of our earth's axis in a year, which add up to sizeable changes over periods measured in millions of years, the axis of our earth has shifted thru many degrees and the 45 mile thick shell of the earth has slid long distances over the plastic interior. The resulting migration of the north and south poles and the equatorial bulge furnished the means whereby mountain ranges were folded and raised to their present heights, coal beds were formed, then sunk under the sea where they were covered up as we find them.

A new idea is introduced: that, as an equatorial bulge lifts a new equatorial zone by means of its newly acquired centrifugal force, the land is lifted higher than the water because it is heavier. (The centrifugal force of anything varies directly with its weight).

Climate and the seasonality of export trade. OTIS P. STARKEY, Indiana University.—Since 1921 the League of Nations (recently the United Nations) has published international trade statistics by months. An analysis of these statistics was made to determine whether the type of climate was reflected in the export trade of various countries. Significant seasonal trends appeared in data for the less industrialized countries but were lacking in industrialized countries. Seasonal fluctuations appeared less pronounced in the decade 1931-40 than in 1921-30, probably because increased diversity of product and greater industrialization. World War II and resulting trade controls largely upset pre-war seasonal trends.

Utilization of Woodland Areas of Morgan County, Indiana

JAMES R. ANDERSON, University of Maryland

The woodland areas of Morgan County are utilized principally as (1) the basis for an important lumbering industry, (2) sites for part-time farms, rural residences, and summer and week-end cottages, and (3) state and classified forests. Most of the woodland is situated in the unglaciated and Illinoian glaciated areas of the county with some in the more rolling parts of the till plain. In these areas much of the land was never cleared for crops, although it was cutover for the timber—sometimes twice. Much that was used for cropland is now reverting to woodland.

The Lumbering Industry

Forests are sufficient to support a sizeable lumbering industry in Morgan County on the margin of rough unglaciated south-central Indiana. In the once-glaciated and the non-glaciated areas of the county, forests are the predominant land use, except in the White River and larger creek bottoms.

One of Morgan County's most abundant resources has been its forests. When the white settlers came, these luxuriant forests. were so dense and widespread as to be a nuisance to the pioneer intent upon getting enough cropland to support his family; consequently, there was much destruction and waste. Following the Civil War, a greater utilization was made of the forests, since the demand for good hardwood lumber was considerable, particularly in the East. In 1870 Morgan County had some 97,000 acres of woodland according to the census; in 1939 only about 40,000 acres were so classified. Thus in seventy years, the forest area was approximately halved.

Morgan County has three main types of forest, the beech-maple, the oak-hickory, and the sycamore-willow-soft maple. The beech-maple type, which is the most valuable, originally occupied much of the northeast part of the county where Crosby-Miami soils predominate. Today less than one-tenth remains and that chiefly on slopes unsuited for farming.

The oak-hickory forest cover is the most extensive type. It is concentrated in the "knobstone regions" south and west of Martinsville, where the more hilly sections are as much as four-fifths forested. Here are found white and red oak, pig-nut and shell-bark hickory, with some ash, sugar maple, elm, and black gum on the lower slopes. Another area that has important stands of the oak-hickory type lies in the central part of the county north of White River. The ridges and slopes of these areas are predominantly forested. Another type is the sycamore-willow-soft maple forests of the river bottomlands; however, only small areas unsuited to farming are now forested.

In comparing Morgan's rank in the state as to forested area, the best available figures are the census enumeration of acres of woodland on farms. This excludes some commercial tracts of timber and also

the state and federal forests. In comparison with other counties, Morgan has a relatively high proportion of its area in woodland. Only 14 of Indiana's 92 counties had more woodland in farms in 1939 than did Morgan; ten of these 14 are in the unglaciated part of the state. In value of forest products Morgan County ranked ninth in 1939.

The importance of sawmills to the early settlers was considerable, for the fine timber was a major source of income to the farmers; and the logging jobs furnished them with employment during the winter months. These sawmills, often small and widely scattered, were set up and operated in many cases only during the winter season. They became so important that from 1850 to 1900 this industry employed more men than any other manufacturing industry in Indiana. Today eleven mills, concentrated in the southern part of the county, are operating; only one is located in the till plain.

Two principal factors have determined the location of the mills: (1) nearness to timber supply and (2) availability of transportation facilities. Eight of the mills have had permanent locations for many years, while three mills have shifted from time to time to keep near to the current timber supply. The eight permanent mills saw five-sixths of the lumber; nearly half of the production comes from the five mills situated in the southwestern part of the county. One of these, located at Whitaker, saws nearly one-third of the county's output. Approximately another one-third of the timber is sawed by three mills in Martinsville.

The Sanders mill at Whitaker, which has been in operation since 1900, is now the largest lumber producer in the county. This long period of activity is exceptional, for many of the mills have been moved or gone out of operation as local timber was depleted. Although the timber resources of the immediate area have now become comparatively small, sizeable forested tracts elsewhere have also been generally depleted; consequently there is little advantage in relocating the larger mills because such a transfer would not greatly facilitate the transporting of logs to the mills. Timber is hauled to some of the mills in Morgan County from points thirty to forty miles away, thus affording evidence that large tracts of good timber are now scarce.

A change in the methods of transporting logs has also been a factor in affording stability to the larger mills. Formerly when there were good tracts of timber close at hand, the farmers did much of the log hauling in the winter when farm work was slack. This gave the farmers a welcome supplementary income and solved the transportation problem for the mill owners. Today the truck has become the principal means of hauling logs. Several conditions, such as the improvement of roads, the introduction of tractors, with the resulting decline of horse and wagon, and the depletion of the forest resources of the immediate area surrounding the mills, have all aided in bringing about the change from wagon to truck. The truck has been an important factor in the survival of the sawmills of Morgan County by permitting them to draw upon a larger district.

Markets for the lumber are widespread. Less than five per cent of it is used within a radius of five miles of the mills, while approximately 15 per cent is sent outside of Indiana, chiefly east to Ohio. Rail shipments were formerly frequent, but improved highways and big trailer trucks have led to increased shipment by truck. Much of the lumber is sold to furniture plants, especially the walnut and much of the oak and maple.

State and Classified Forests

Although much land with rough terrain in the more isolated parts of the county is best adapted to forests, the present state forest preserve and classified forests on private holdings account for only a small part of such land. More understanding and cooperation among forest owners and more encouragement and purchase by state and federal government are needed to accomplish better land use adjustment on much of this land.

In the south-central part of the county where a contiguous area of unglaciated rough upland affords little agricultural possibilities a state forest preserve has been established. As of July 1, 1949 there were 4,410 acres of this preserve in Morgan County with more of it extending southward into Monroe. Since July, 1949 additional purchase of 2,891 acres of land has been made in the area immediately adjoining the Morgan-Monroe Preserve at an average purchase price of only $10.24 per acre. Much of this land was in extremely bad shape. Replanting some of the badly eroded ridges with pine during the thirties combined with years of protected growth is gradually improving the timber stands and holding the soil.

Classified forests on farms are an attempt to persuade farmers to protect and rejuvenate their timber stands by keeping out livestock. As of March, 1950 there were only 20 classified forest owners in Morgan County with 1,438 acres classified. When classified, the land is valued at a $1.00 per acre. Indiana Department of Conservation records show that pre-classification values for these classified tracts varied from $5.00 to $35.00 per acre. However, the cost of fencing small tracts on the farm often keeps a farmer from classifying his woodland. Farmers are generally not aware that protected forests can become an important source of income on farms with much woodland. Growth studies indicate that the annual saw timber growth in Morgan County is about 6,000,000 board feet which growth has an annual value of about $120,000 to the landowners. This does not include growth cut for fuel wood, fence posts, saplings for furniture, and other uses. A more widespread educational program along with further financial inducements are necessary to make classified forests effective.

Part-time Farms, Rural Residences, and Summer and Week-end Cottages

Since the depression years of the thirties, some significant changes in the rural landscape have been taking place in parts of Morgan County. Nowhere else in the county have changes been so rapid as in the largely wooded and more dissected areas of upland. The part-time

farm, the rural residence, and the summer cottage have greatly increased in number.[1] The "back to the land" movement of the thirties, stimulated by the great economic depression, has been followed by a period of war prosperity, during which years urban housing became critically short in many centers where war industries were developed, as in Indianapolis. Fast hard-surfaced highways, improved automobiles, the eight-hour day, and the five-day week have made it increasingly easy for more urban-employed workers to seek the amenities of rural living. The wooded uplands of Morgan County are well located as sites for rural dwellers. Here is land available for subdivision nearer to Indianapolis than any other area of cheap land. Furthermore, because this land is situated on the industrial side of Indianapolis, slow crosstown traffic is avoided and rapid commuting is favored. Lack of zoning laws in Morgan County makes it possible to erect any type of house. Certain restrictions on subdivision of land and building in Marion County have encouraged many to take advantage of the absence of rural zoning in Morgan County.

The preliminary releases of the 1950 census show a marked population increase of 3,911 between 1940-50. About 3,000 of this increase occurred in rural areas. This is the largest decade increase in the county in one hundred years. This marked increase is a notable reversal of trend for a county that had a population decline between 1910 and 1930 and only a very small gain from 1930 to 1940. This marked increase is owing largely to the movement outward from Indianapolis of people wishing to take up residence in the country.

A contiguous area of about 25 square miles in the wooded rough central part of the county was mapped as an area having a great concentrated influx of people during the past ten years. In 1936 there were 157 dwellings in the area. In August, 1949 there were 295 houses, only 41 of these were on full-time farms. The others were rural non-farm residences and part-time farmsteads many of which have been occupied only very recently. Of 51 rural non-farm families interviewed in different parts of the county, 33 had lived at their present residence five years or less; 22 families had lived in their present homes for only two years or less. Only nine had established their present home before 1940.

The motivation behind this shift of non-farm residents to the open country-side is a complex of several desires and necessities. Table I classifies the replies to the question "Why did you move to this location?" Many of the replies were in terms of strong convictions about the country being a better place to live and to rear children. The recency of the last depression combined with the opportunity and necessity of finding a residence on the countryside surrounding urban centers re-

[1] The part-time farm as used in this discussion is one having over three acres of land or an annual value of products of at least $250 and whose operator is engaged primarily in an occupation other than farming. A rural residence is a holding of less than three acres or on which less than $250 worth of produce is produced by the occupant.

sulted in an accelerated movement into Morgan County. Practically all of those interviewed considered their present residence as permanent rather than temporary.

TABLE I. Replies to the Question: "Why did you move to this location?"

Classification of Replies	Number of Replies
Lower living costs	13
Desire for the amenities of rural life	12
To rear family away from urban influence	9
To get out of Indianapolis and Martinsville	7
To get a place to retire	7
Wanted a week-end and summer vacation place	6
To farm	5
Living on the old "homeplace"	5
Unable to find housing in Indianapolis	4
Security	2
Conveniently located near to work possibilities	2
For health	2

Rural non-farm residents have come from a wide range of income groups and have tended to concentrate in parts of the rough and wooded uplands for different reasons. Those with higher incomes often came seeking week-end and summer vacation homes. The scenery and isolation of the area have attracted many. Many discovered they liked living in the country and became permanent residents commuting to urban jobs.

Lower income groups have concentrated on the ridges of the dissected uplands because here was land that they could afford. Furthermore, there are no building codes specifying the type of house which can be built. Some of the ridge roads are lined at intervals of less than a quarter of a mile with small houses and shacks. Very few of the newly constructed houses are substantial and comfortable for the size of the family generally occupying them. Some parts of the wooded uplands may be appropriately designated as rural slums.

Nearly one-half of the residents over 18 years of age were reared in cities. Another one-third were reared in the rural communities where they are now residing. The remaining one-fifth were reared in other rural areas. Four-fifths of the residents over 18 years of age had lived in a city at some time or other. Thus there is a strong movement from the cities and a tendency to take up residence near the old homeplace. This high proportion of urban-reared residents has encouraged neglect of the land on which the residences are situated, because so many lack the know-how to use it properly.

Practically all of the rural non-farm residents and part-time farmers own their land. Only three out of 51 families interviewed are cash renters. The average size of holding is 21.9 acres. Most of the hold-

ings are less than 50 acres with about two-fifths of them less than ten acres. On the average only 5.8 acres of each holding is cleared land, the remainder being in woodland suitable for fuel but having very little merchantable timber. Only one-fourth of the owners are making any use of their woodland other than for recreational purposes. One-third of the residents are using some of their land for crops. However, only one-sixth of the total acreage in the 51 holdings is being used for crops. Most of the cropland is being used for corn and soybeans. Low yields are characteristic.

Three-fourths of the residents have gardens, but the benefits derived vary greatly. Practically all of the gardens are maintained only for home use with very little grown for sale. Production for sale is uneconomical because of competition with commercial farms, but food produced for home use assumes a retail value which if grown can mean a considerable saving. Most of the produce is consumed fresh, although some is canned and frozen. A big well-cared-for garden is the best single practical use that most of the residents can make of their land.

Nearly half of the residents have some fruit trees planted either for home use or small commercial production. From the standpoint of physical conditions these small orchards are generally well located, but they will be a financial loss to their owners as a commercial enterprise. Existing commercial apple orchards in areas where rural non-farm residents are numerous have probably encouraged many of the uninitiated to plant small orchards. Several are growing small fruits which are much better adapted to the average size of holding. Strawberries, raspberries, and blackberries yield well on some of the soil types found in the dissected uplands. These come into bearing much more quickly than peaches and apples; furthermore, they require less skill in caring for them. In addition to these advantages, market opportunities in Indiana for these small fruits have been exceptionally strong since the war. The increased demand for them is partially explained by their adaptability to freezing. Indianapolis offers a nearby market for commuters to sell a considerable share of their fruit as fresh produce through door to door sales. If only fruit for home use is all that is wanted, these small fruits likewise have special merit for small holdings on which farming is a secondary consideration.

Livestock kept without growing the feed is probably a waste of time on small holdings. A few chickens to dispose of garbage is a possible exception. If grain and pasture can be provided on the holding then a cow and a hog are likely to lower food costs. Two-fifths of the 51 families interviewed are keeping chickens. Practically all of the flocks kept were for home use, with sale of eggs and fryers only incidental.

Only nine of the 51 residents are keeping one or more cows per family. One-sixth of the families are keeping some other livestock, principally some rabbits and a hog or two per household. For many of the residents livestock other than chickens are too confining; particularly is this true of milk cows. Since one-half of those over 18

years of age were reared in urban centers, it is understandable why the livestock population is not greater among the rural non-farm residents. Furthermore, most of these residents do not have the capital or know-how to start raising livestock.

Since most of the residents are engaged in jobs having a 40-hour week and since commuting time from most of Morgan County to the outskirts of Indianapolis is an hour or less each way, there is considerable opportunity to make the land count for much more in boosting family income than it generally does at the present time. Many rural residents could provide themselves with a better living if more attention were given to the growing of better gardens and in some cases keeping some livestock. Lack of know-how, inadequate capital, and an unwillingness to be tied down by growing gardens and keeping livestock prevent many from benefiting economically from rural residence.

A heavy concentration of summer and week-end cottages has developed around the wooded shores of Lake Patton in the central part of the county. Since the late thirties this artificial lake has been much utilized for week-end and summer vacations of Indianapolis and other urban dwellers. However, marked increase in total number of cottages around the lake has occurred since World War II. Also several who first were only week-end and summer vacation visitors have now become permanent residents commuting to urban jobs.

Summary

Morgan County near Indianapolis should have a profitable lumbering industry so long as adequate timber remains available. Sizeable areas ill-adapted to farming but suitable for forest growth make it likely that lumbering will continue relatively important.

The state and classified forests are initial steps toward scientific forestry—the desirable land use for isolated rough areas.

Rapid recent population increase reflects nearness to Indianapolis, improved roads and automobiles, reduction in length of work day, scarcity of urban housing, and greater strictness of suburban building codes. People seek lower living costs, the amenities of rural life, a better chance to rear a family, a place to retire, a week-end and summer place, and security.

Greatest recent growth of rural population has occurred on some of the poorest, largely wooded land. Urban people of the higher income groups have been attracted by the scenery and isolation of hilly wooded areas. Those of the lower income groups have come to the rough uplands because the land is cheap.

Relative Location and the Growth of Terre Haute

THOMAS FRANK BARTON, Indiana University

A population graph of Terre Haute presents a challenging problem because it is the only large city in Indiana whose population declined for two decades and whose total estimated population in 1950 is less than its peak was in 1920. The city's most rapid growth took place between 1900 and 1910 when its population increased from 36,673 to 58,157. In 1920 its population reached a peak of 66,083 and then declined to 62,810 in 1930 and 62,693 in 1940. A preliminary release indicates that Terre Haute's numbers increased to 64,097 in 1950, a gain of only about 1,400.

These statistics stimulate one to ask questions. Why did the city grow so rapidly between 1900 and 1910? What factors contributed to the decline between 1920 and 1940? What are the future prospects? etc.

Perhaps in the past too many of those who have been both economically and academically interested in Terre Haute's growth have concentrated their attention upon the political city and have failed to give adequate consideration to its relative location and its neighbors.

There are many large and small cities near this Queen City of the Wabash. Approximately 170 miles to the north is Chicago and 100 miles to the south is Evansville. Seventy-three miles to the northeast is Indianapolis, capital of Indiana, while 130 miles to the northwest is Springfield, capital of Illinois. It is interesting to note that Terre Haute is almost equidistant from the metropolitan areas of Chicago, St. Louis, and Cincinnati. Lines connecting these metropolitan areas form a triangle enclosing Terre Haute. Although all these cities are only a few transportation hours from Terre Haute they are all larger and compete with it in many ways.

About an hour's drive or between 50 and 65 miles from Terre Haute are a number of small cities, which exert an important influence upon the flow of goods and people in the area surrounding this Queen City of the Wabash. Starting on the northwest Danville, Illinois, the largest of the encircling group is 59 miles away. Crawfordsville, Indiana, lies 62 miles to the northeast. Continuing in a clockwise direction around Terre Haute, we find Greencastle 40 miles to the east; Bloomington 59 miles to the southeast; Vincennes 58 miles to the south; Lawrenceville, Illinois, 66 miles to the southwest; and Mattoon, Illinois, 63 miles to the west southwest. In contrast to Terre Haute these cities have had substantial growth during the last few decades.

Historic Perspective

Terre Haute's early growth was due in part to its central location between the two great waterway systems of transportation that

flourished in the states carved from Northwest Territory during the first half of the nineteenth century, namely the Ohio River and the Great Lakes. It was to open up the comparatively inaccessible area between these two waterways that the federal government constructed the National Road. This road reached the Wabash city in 1838. Terre Haute and Richmond were important centers on this road. In part because of the impetus of this early start they are the west and east anchors of a semi-circular group of cities (population 25,000 or larger) which form an arc to the north around Indianapolis.

Terre Haute's early growth was also aided by the Wabash-Maumee Canal which reached it in 1849.

Although the founding fathers were unaware of the fact, they located this city in the northern edge of the Wabash Lowland. This physiographic province proved to be better equipped by nature for the development of agriculture than any of the other six physiographic provinces in southern Indiana. Today, after a century of machine agricultural development, Terre Haute finds itself in a southerly projection of the "Feed Grains and Livestock (Corn Belt)" type of farming region. This region is considered by many to be the agricultural heart of the United States and North America.

From the standpoint of minerals, Terre Haute is located in the northeastern edge of the Eastern Interior Coal field and the Illinois-Indiana petroleum field. This city's trade area has long been known for its coal industry, and its easily-mined comparatively low-priced coal is one of its greatest assets. In addition to the local petroleum supply, this city sits within one of the greatest concentration of national pipe lines in the world. (There remains the problem of adequately tapping these supplies.) Petroleum pumped to the Atlantic Coast from the Mid-continent field in Texas and Oklahoma passes through pipe lines laid across Indiana, Ohio and Pennsylvania.

Besides petroleum pipe lines, there are good transportation facilities of other types. Two national highways, U.S. 40 and 41, cross here and railroad lines radiate out in all directions. The Trans World Airline and the Southern Airline Routes cross here.

These and other favorable factors of relative location are important geographic assets.

During the last half of the 19th century as the local resources of forest, soil and minerals were exploited the city had a substantial growth. And during the first decade of the 20th century, industries established here gave it its greatest increase in population—over 21,000.

Why the Decline?

With all these favorable factors in relative location and with such a good record of growth for sixty years between 1850 and 1910, why did the population decline between 1920-1940 and show a gain of less than 1,400 during the past decade?

The writer continues to study the problem but would like to list some possible factors for your consideration.

1. The rapid mechanization of agriculture and mines has greatly reduced the employment opportunities of these two industries.

2. Terre Haute's trade territory as a whole has passed through the lucrative exploitation stage. The forests and soils have been mined and the near-surface and easily stripped coals removed from comparatively large areas.

3. Much of the crop land has proven economically submarginal or marginal in character in competition with other cultivated land, for example, central Indiana, Illinois and Iowa. Although located in a southerly peninsula of the Corn Belt, much of the land is too wet, too sandy, too acid and/or infertile, and too often subjected to flood to be classed as good crop land. A large number of farms in Terre Haute's trade territory are classified as "self-sufficing" and "part-time" farms. Thousands of acres of land have been subjected to strip mining operations and removed from cultivation or held for future mining development.

4. Counties in the city's trade territory have had a low population increase or have declined. Only three Indiana counties lost population between 1940-1950 and two of these, Vermillion and Parke are in this city's trade area. Across the Wabash in Illinois, Clark and Edgar counties reached their peaks in population in 1900 and have since declined.

5. A large number of people who make their living here do not live within the political city. All-weather roads and the automobile make it possible for more and more people to live in the environs outside the city's political boundary. For example, the population of Vigo County, of which Terre Haute is the county seat increased from 99,709 to 104,931, an increase of over 5,000; yet the city had an increase of less than 1,400. Some of the people do not even live in Vigo county but drive daily from adjacent Indiana counties and many from Illinois cities such as Paris, Marshall and Martinsville.

6. There is a growing tendency of industrial companies to place their factories outside the political boundaries of cities and many workers wish to live near the factory.

7. Industry is moving from metropolitan areas to small cities. According to a National Industrial Conference Board report in May 1948, a survey indicated that "there was a large increase in the number of new plants placed in cities of 10,000 or fewer."

8. Present stagnation and in the past some recession in the political boundaries.

9. Some people have moved from within the city to its environs for a number of reasons, such as to secure larger settings for their homes, escape higher taxes, and avoid the winter smog.

10. Continued increase in the use of former residential land within the city for non-residential purposes.

These and other factors should be evaluated carefully in interpreting the past and considering the future of Terre Haute.

Variations in the Stratigraphic Position and Character of the Base of the Mansfield Sandstone in Southern Indiana[1]

CLYDE A. MALOTT, Indiana University

The eastern dissected fringe of the basal Pennsylvanian system of rocks overlaps northward and eastward on various formations of the Mississippian system in its passage across southwestern Indiana along the eastern margin of the Illinoian basin from Perry County on the Ohio River to Benton County in the northwestern part of the State. The basal aspects of the Pennsylvanian system in Indiana have been assigned to a single formation under the name of the Mansfield sandstone since the detailed studies by Hopkins in 1896. A single lithic name has been tolerated because it applies fairly well northward from Orange and Martin counties where its thickness only locally exceeds 100 feet or slightly more up to the Lower Block Coal of the Brazil series, which is defined as its upper limit. Southward, it appears to be divisible into several formations or stratigraphic units consisting of sandstones, local conglomerates, shales, coals, and rarely local limestones, all variable in thickness and lateral extent, and aggregating as much as 400 feet up to what may be recognized as thin representatives of the Brazil block coals. No detailed studies of these formations have been made. The local variations in thicknesses and the inconstant areal extents of the formations have discouraged stratigraphic designation, though local sequences have long been recognized. A massive, cross-bedded sandstone, and locally a coarse, gritty and pebbly sandstone, is prevalent at or near the base of the formation. Locally it digs deeply into the underlying formations along a pronounced erosional unconformity. It is usually quite unlike the underlying formations and is clearly identifiable as the basal phase of the Pennsylvanian system. As such, the name *Mansfield sandstone* is more fitting as a reference term than as a stratigraphic unit with a definite fixed bottom and top. It is not the purpose of the present paper, however, to present details of stratigraphic sequences in the Mansfield formation, but rather to discuss the stratigraphic position of the base of the formation and to call attention to some of the lithic variations at and near the base.

The unconformity at the base of the Pennsylvanian system in Indiana is very marked and is manifested in several ways. First, the base of the Pennsylvanian system overlaps the entire Mississippian system from south to north along the eastern edge of the Illinoian basin in Indiana. It rests on the Kinkaid limestone, the highest Mississippian formation in the Illinoian basin, along the Ohio River in Perry County, and on the New Albany shale of late Devonian age in an outlier near Remington of southern Jasper County, the northern mostknown occur-

[1] (Posthumous publication. Dr. Malott died August 26, 1950)

rence of the Pennsylvanian in Indiana. This is a stratigraphic overlap of 1,850 feet in 200 miles. Second, an easterly overlap of the Mansfield from younger to older formations is readily demonstrated northward from Perry County, locally amounting to several hundred feet. Third, the base of the Pennsylvanian system rests on an uneven topography, consisting of valleys and ridges with local reliefs up to 150 feet or more. Fourth, the Pennsylvanian formations dip in a westerly direction at rates slightly less than the underlying formations. The Mississippian formations have a westerly dip of 30 feet or slightly more to the mile, while those of the Pennsylvanian dip about 25 feet to the mile. The slighter dip of the Pennsylvanian formations, however, is not readily apparent in the Mansfield, because this formation does not have persistent stratigraphic units nor is bedding so uniform and dependable as in the underlying formations. Some aspects of these several expressions of the Pennsylvanian-Mississippian unconformity found in several southern Indiana counties constitute the chief contribution of this paper.

In southern Perry County near the Ohio River the Mansfield formation intermittently rests on the Kinkaid limestone formation over an area of several square miles, chiefly along and near Little and Big Deer creeks. The altitudes of the base are quite variable, ranging from 750 feet on the high ridge near State Road 66 four miles west of Rome to as low as 435 feet on Caney Creek two and one-half miles northeast of Cannelton in the area of the outcrop of the unconformity. The Kinkaid limestone, previously described by the writer (3) under the name of Negli Creek limestone, is the highest described formation of the Chester series and the Mississippian system in and about the margins of the Illinoian basin. Locally, in the area of the outcrop of the Kinkaid limestone, the base of the Mansfield cuts deeply below into various Chester formations and rests either on the Degonia sandstone (Mt. Pleasant), Clore shales, Palestine sandstone (Bristow), or Menard limestone and shales (Siberia), more than 100 feet below the Kinkaid. At and near Lafayette Spring and Rock Island in the Ohio River nearby, along State Road 66 about three miles east of Cannelton, the base of the Mansfield is composed of a massive, cross-bedded, gritty and pebbly sandstone up to 60 feet in thickness which rests on the Menard formation at an altitude of about 380 feet, considerably below high water level of the Ohio River. One-half mile north of Lafayette Spring a stratigraphically higher phase of the Mansfield sandstone rests on the Kinkaid limestone at an altiude of 480 feet, 100 feet higher than the base at and near Lafayette Spring. Eastward across the wide valley of Deer Creek and only about one and one-half miles from Lafayette Spring, the base of the Mansfield is above the Kinkaid limestone at an altitude slightly in excess of 600 feet. The great difference in the altitudes of the base of the Mansfield on the two sides of Deer Creek is accounted for in part by the difference in the stratigraphic position of the base, in part by a fault with an upthrow on the east of approximately 100 feet, and in part by the normal westerly dip of the rock

systems. Farther eastward along the wooded bluff north of the Ohio River, the base of the Mansfield cuts down through the upper Chester formations to an altitude of 520 feet within one mile, approximately 100 feet below the Kinkaid limestone. As the base of the formation descends to lower levels, the white, milky-quartz pebbly phase of the Mansfield appears and thickens to a bed 55 feet thick. A thin streak of coal and a sandy fire-clay occurs 15 feet above the base in the conglomerate about one mile east of the mouth of Deer Creek. The pebbly phase of the Mansfield is topped by 50 feet of coarse, cross-bedded, friable sandstone which reaches to the upland level some 250 feet above the Ohio River. The Lafayette Spring locality is one of the most prominent occurrences of the pebbly phase of the Mansfield, and here, as elsewhere, it occurs where the base digs deeply below its normal stratigraphic position for the locality.

Some six miles north of the Lafayette Spring locality, the base of the Mansfield is normally below the Kinkaid limestone, except for one known small area along State Road 37 one mile northwest of the village of Leopold, where the base is sufficiently high to permit the Kinkaid limestone to show at an altitude of about 685 feet. Elsewhere through the middle and northern parts of Perry County, the Mansfield rests on the Degonia, Clore, and Palestine formations, and in the extreme north, locally on the Menard formation. At no place north of the Lafayette Spring locality in Perry County does the pebby sandstone phase occur more than a few feet in thickness, nor does the base cut deeply below its normal stratigraphic position. In Perry County there is only a slight easterly overlap of the base of the Mansfield. It is much less apparent than the easterly overlap farther north. The most easterly exposures of the Mansfield are near the village of Oriole, east of Oil Creek valley in the northeastern part of the county, where a sprangling outlier of massive, cross-bedded, loosely-bound, locally gritty sandstone caps the ridges below the Degonia sandstone at an altitude of about 775 feet. It occurs in mound-like hills east of Mt. Pleasant which rise 50 feet or more above the flat, expansive plain developed on the Degonia sandstone. A similar loose sandstone is present in the vicinity of St. Croix some 75 feet lower stratigraphically, and a short distance east of the town iron oxide occurs in peculiar twisted ribbons in the soft sandstone above the upper Chester shale, probably Menard, upon which it rests.

Along State Road 37 on the ridge west of Branchville and north of Bandon, the Mansfield is exposed in the road cuts where cross-bedding resembles layers of rock which appear to be dipping steeply southward. The underlying Chester formations, consisting of the Degonia, Clore and Palestine formations belie the appearance of a strong southward dip of the Mansfield beds. The Mansfield descends to the level of the valley floor of Anderson Creek near Adyeville, some three miles up stream from St. Meinrad, at an altitude of about 440 feet, resting close above the Palestine sandstone. In the westward stretch of some 15 miles from Oriole to the vicinity of St. Meinrad, the base

of the Mansfield changes little from its stratigraphic position, resting on the Degonia sandstone with no evidence of an easterly overlap.

Northward from the massive, pebbly sandstone of the Lafayette Spring locality of southern Perry County to perhaps as far as the French Lick locality in western Orange County, the basal Mansfield shows no unusual aspects. It is usually composed of medium to coarse sandstone at the base which is more or less highly impregnated with iron-oxide from a few inches to a few feet. At places the coarse sandstone base is succeeded by a light-colored sandy shale or fire-clay and a thin coal seam some few feet above the base. The coal is commonly followed by medium-grained, cross-bedded, massive sandstone. Where the sandstone is massive it dominates the outcrops along the steep-sided valleys. Considerable shale and shaly sandstone is present in the formation. The more massive and thicker beds of sandstone show locally in great cliffs along the sides of the valleys and ravines, but rarely do single sandstone cliffs exceed 75 feet in height. Even in the spectacular bluffs at and near Lafayette Spring on the Ohio River, detailed sections show that much of the Mansfield is composed of shales. In the towering bluff from which a large mass of sandstone has fallen into the Ohio River to create Rock Island, an historic island marker in the Ohio River near Lafayette Spring, five beds of sandstone, aggregating 122 feet in thickness, and four intervening beds of shale, totalling 103 feet in thickness, composed the measured 225 feet of rock in the bluff. At Lafayette Spring a short distance away, two beds of sandstone 80 feet thick and two beds of shale of the same total thickness form the measured bluff of exposed rock at this historic spot.

In the extreme northern part of Perry County the base of the Mansfield rests on or near the Menard (Siberia) limestone, having descended stratigraphically approximately 110 feet in 25 miles north of the Ohio River at Lafayette Spring. Near Birdseye in eastern Dubois County, the massive basal sandstone of the Mansfield rests on or near the Menard limestone at an altitude of about 660 feet and about 175 feet above the well known Glen Dean limestone. In southern Crawford County, near the fire-tower in the vicinity of West Fork, the Mansfield rests on the Waltersburg formation at an altitude of about 800 feet. West of English the eastern fringe of the main body of the Mansfield is down on the massive Tar Springs sandstone, a position it holds northward through much of southwestern Orange County to near French Lick.

Crawford County has a very notable but small outlier of the Mansfield surprisingly far east of the eroded fringe of the main formation. Pilot Knob, a high isolated hill, six miles south of Marengo and seven miles southeast of English, in the northeast one-fourth Sec. 36, T. 2 S., R. 1 E., is capped by a remnant of coarse, cross-bedded, iron-impregnated sandstone, containing local gritty streaks and infrequent small white quartz pebbles. Pilot Knob is the highest point in Crawford County, reaching an altitude of about 925 feet. It rises 100 feet or more above the general upland surface and forms a land mark

observable for miles about. The Mansfield cap is not over 100 yards across and has a thickness of about 25 feet. It rests on Chester shale equivalent to the Tar Springs at an altitude of about 900 feet and about 60 feet above the Glen Dean limestone which outcrops nearby. This position is somewhat lower stratigraphically than the position of the base of the main body of Mansfield two or more miles west of English and approximately 10 miles west of Pilot Knob, where it rests on or slightly above the Tar Springs sandstone about 90 feet above the Glen Dean limestone. From the Birdseye locality in eastern Dubois County to Pilot Knob, a distance east and west of 19 miles, the base of the Mansfield overlaps eastward about 115 feet, ranging from the Menard limestone 175 feet above the Glen Dean limestone to within the Tar Springs formation 60 feet above the Glen Dean.

At the railway tunnel three miles southwest of French Lick in southwestern Orange County, the Pennsylvanian rests on the massive Tar Springs sandstone about 60 or 70 feet above the Glen Dean limestone. Farther north appearances of the Tar Springs are rare. No Tar Springs sandstone is known to occur north of Shoals in Martin County. Hence all of the upper Chester formations, consisting of the Kinkaid, Degonia, Clore, Palestine, Menard, Waltersburg, Vienna and Tar Springs, and aggregating about 290 feet, have been overlapped one by one in about 50 miles north of the Ohio River. The Mansfield rests on the Glen Dean limestone or on the Golconda limestone to as far north as the Orange-Lawrence county line. In Martin County the Glen Dean is usually present along the western outcrop of the Chester series except locally, and continues present into southeastern Greene County, where it is intermittently present in the southern parts of Township 6 North nearly to the village of Koleen. The Mansfield rests on three to five feet of the bottom part of the Glen Dean limestone in the western part of the abandoned railway tunnel beneath the Mansfield ridge just west of Owensburg at an altitude of about 760 feet. The base of the Mansfield here is composed of a few inches of sandy iron ore followed by cross-bedded sandstone. A local coal in the Mansfield has been mined in the ridge about 50 feet above the base here. The northernmost known occurrence of the Glen Dean limestone is in a small valley near the center of Sec. 12, T. 6 N., R. 5 W., about four miles southeast of Bloomfield. Here about five feet of the Glen Dean limestone are exposed with the base of the Mansfield resting on it at an altitude of about 540 feet. The base is composed of a few inches of sandy iron ore followed by a shaly sandstone. Since much of the eastern fringe of the Mansfield sandstone north from southern Perry County occupies the ridge crests of a soil-covered mature to old age topography of a much dissected upland, the base of the formation is nearly everywhere obscured and extended exposures are rare. While local exposures are common, good sections of the formation are difficult to obtain.

An unusual lithic aspect and a special phase of sedimentation are exhibited near the base of the Mansfield just below the high ridges of the eastern fringe of the formation in local areas of western Orange

County, where some 10 to 20 feet of the formation have been quarried in the past for the manufacture of whetstones. The localities of known occurrence and the special features of these beds in the Mansfield have been set forth in detail by Kindle in the Twentieth Annual Report of the Indiana Department of Geology and Natural Resources for 1895 (1). One outstanding locality is in and near Sec. 32, T. 2 N., R. 2 W., about two and one-half miles west of French Lick, and another is in and near Sec. 23, T. 3 N., R. 2 W., about four miles northwest of Orangeville. The whetstone rock is composed of very fine-grained, compact, angular quartz sand. The quartz grains are about 0.02 millimeter in size. The well compacted sand is arranged in well defined layers from less than one inch in thickness to layers of one foot or more. Some of the layers are laminated and may be split readily. The whetstone layers are disposed horizontally in some of the old quarries and in others are distinctly composed of cross-bedding, departing from the horizontal 10 to 15 degrees. The layers have very smooth surfaces. In a number of the quarries standing trunks of *Lepidodendron* trees are described as rising through the layered whetstone rock. These tree trunks are from a few inches to two feet or more in diameter, and are composed of the same fine-grained sand, but unstratified, and have a rough bark composed of coal. They are reported as standing on a thin coal which immediately underlies the whetstone rock. The coal bed apparently is near the very base of the Mansfield. Fossil ferns also occur in the whetstone beds, and some of the layers are marked by trails made by crawling and walking animals, though the latter are rare. The base of the Mansfield with the coal near the bottom is at a normal position stratigraphically. Northwest of Orangeville the base is on the Golconda shale at an altitude of about 800 feet, and the whetstone beds begin not more than 10 or 15 feet above the base. The conditions of sedimentation were quiet and stagnant, permitting a coal swamp to exist, and later the vegetation of the coal swamp was rather quietly buried with trees still standing in the swamp. The currents of the inundating sea at first brought in only the very fine sand, apparently in localized, protected areas. A secondary peculiarity of the whetstone beds is the presence of intersecting joints developing various sized diamond-shaped blocks of stone, about which iron-oxide has accumulated and penetrated from one to several inches, frequently producing a striking pattern in the white stone.

Some of the variabilities of the altitudes of the base of the Mansfield formation in the western part of Lawrence County were shown by the writer in 1946. The eastern edge of the much eroded fringe of the main body of the base of the Mansfield has an altitude generally about 800 feet, which is some 70 feet higher than the Buddha outlier 10 miles or more to the east. It is certain that the Buddha outlier is an isolated remnant of the pebbly phase of the Mansfield deposited in a pre-Pennsylvanian valley trough which cut deeply below the normal position of the Mansfield base. It appears too deep to be wholly accounted for by a pre-Mansfield valley and is thought to represent a truncation of an easterly

overlap, suggesting some aspects of a pre-Mansfield Chester escarpment not greatly unlike the one which today marks the eastern boundary of the Crawford Upland. No other locality in Indiana is known to have such a great stratigraphic range in the overlap of the base of the Mansfield sandstone.

The main body of the Mansfield in the southwestern part of Lawrence County has considerable variation in the altitudes of its base, especially west of the eastern fringe where data on the base are more readily available. The normal stratigraphic position of the base in Lawrence County is on the Cypress and Golconda formations, but in the Bryantsville-Huron area the base digs deeply below its normal stratigraphic position, in places coming below the Beech Creek limestone, and has a local relief in excess of 100 feet. On U.S. Highway 50, one and one-half miles southwest of Bryantsville, the base rests on the Elwren shale at an altitude of 765 feet. At the abandoned kaolin mines three miles west of Bryantsville, the Mansfield base of coarse, cross-bedded, massive sandstone is at the horizon of the Beech Creek limestone about 700 feet in altitude. Two miles southwest of the kaolin mines, the base of the Mansfield is at its normal position on the Golconda formation at an altitude of 760 feet. These altitudes not only represent the westerly dip of all the formations of some 30 feet per mile, but they show a variation in stratigraphic position as well.

In the locality west of Williams, Lawrence County, the Mansfield bites most deeply into the Chester formations. Here, a loose, pebbly phase of the Mansfield rests on or near the Beaver Bend limestone at an altitude of 595 feet, stratigraphically 120 and 165 feet below the tops of the Cypress and Golconda formations. The loose, pebbly Mansfield has been dug or quarried for road material just north of the overhead bridge across the railway on State Road 450. Some redeposited iron-stained clay derived from the pre-Mansfield clay residue of the Beaver Bend limestone occurs in the base of the Mansfield in the quarry pits, along with some fragments of redeposited white kaolin. The pebbly phase of the Mansfield here occupies a pre-Mansfield valley as much as 150 feet below the nearby pre-Mansfield uplands This old pre-Mansfield valley with its pebbly fill of the Mansfield formation extends west and southwest some four miles to the well developed, pebble-filled pre-Pennsylvanian valley in the Indian Springs and Trinity Springs localities, mapped and described in 1931 by the writer.

In the Huron area, at altitudes varying around 675 to 700 feet or slightly more, local beds or basin-like pockets of white kaolin, often referred to as Indianaite, have been developed. While some white kaolin has been found elsewhere at the base of the Mansfield and some of the Chester sandstones, the Huron deposits are the largest and most abundant and some exploitation of them has occurred there. No white kaolin is known to occur at any place above the Beech Creek limestone, and only traces are known below the horizon of the Beaver Bend limestone. The deposits of the Huron locality are not believed by the writer to belong to the Mansfield formation, but represent a weathered, leached,

and altered residuum and colluvium of the sedentary clays derived from the Beech Creek limestone, and not removed before the deposition of the Mansfield sandstone upon them. The pre-Mansfield Beech Creek residual clays called mahogany clays by various geologists are far more widespread than the locally developed basins of white kaolin from these sedentary clays. The white kaolin deposits are confined to areas in the Huron locality where the Mansfield has been deposited upon them in pre-Mansfield depressions or valleys cut below the normal position of the base of the Mansfield of the locality. The Mansfield in such localities is a coarse, cross-bedded, massive sandstone, occasionally containing grit and a few small pebbles. Also, in places it contains kaolin fragments aligned along the cross-bedding, indicating erosion and redeposition of the pre-Mansfield white kaolin.

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Ground Water Provinces of Indiana

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Ground water supplies are found in most parts of Indiana, but owing to the diversified character of the water bearing materials, the manner of occurrence is not the same. The purpose of this report is to present for the first time a regional classification of ground water resources in Indiana based upon areas characterized by a general similarity of the principal occurrences. Such a classification is of value for comparative and descriptive purposes. The distinctive features of the water bearing formations are described for each province. The limits of each division set forth herein are based primarily upon one or more of the following conditions: (a) the extent of the important surficial water bearing formations, (b) the extent of the important bedrock water bearing formations, (c) physiographic and topographic conditions. Also, the sources of the public water supplies of over 350 cities and towns, logs of several thousand water, oil, and gas wells, information gathered from questionnaires sent to over 500 water well drillers in the state, and personal observations were used in determining the location and extent of the provinces and their subdivisions.

Ground water provinces for the United States have been delimited and described by several writers. Fuller (1, p. 35-40) described only the eastern United States. Ries and Watson (4, p. 330-337) divided the United States into 8 provinces. However, later revisions of their text book incorporated Meinzer's (3, p. 193-309) 21 provinces. Tolman (5, p. 499-555), while accepting most of Meinzer's (3, p. 193-309) classification, modified it by dividing the Pacific Coast belt into three provinces. All these classifications are based upon the presence of one important group of aquifers in a subdivision or province, or, where more than one of the principal groups of aquifers occur, on the coexistence of two or more of the most important groups as a means of delineating the province.

Indiana, under the Meinzer (3, p. 201-244, 283-291) classification, would fall into two of the provinces. The largest part of the state would lie in the North-central Drift-Paleozoic province and would encompass all of glaciated Indiana. The remainder, about one-sixth of the area of Indiana, or the unglaciated region, is included in the South-central Paleozoic province. As the names suggest, the above division was made on the basis of the ground water supplies being obtained from glacial sands and gravels or from Paleozoic sandstones and limestones.

The classification proposed herein for Indiana also divides the state

[1] Published by permission of the Chief Engineer, Indiana Flood Control and Water Resources Commission.

into two main ground water provinces, but differs from the above classification on boundary and subdivides these two provinces into a total of eight sections in which similar conditions exist (Fig. 1). The provinces with their subdivisions are:

I. Northern Indiana Glacial province
 a. Lake and Moraine section
 b. Northern Till Plain section
 c. Southern Till Plain section

II. Southern Indiana Bedrock province
 a. Ordovician Limestones and Shales section
 b. Silurian and Devonian Limestones section
 c. Devonian and Mississippian Siltstone and Shales section
 d. Mississippian Limestones section
 e. Mississippian and Pennsylvanian Sandstones section

I. *Northern Indiana Glacial province.* The Northern Indiana Glacial province is in the area of the Wisconsin glaciation. In general the southern margin of the Shelbyville moraine marks the boundary between the Northern Indiana Glacial province and the Southern Indiana Bedrock province. A deviation from the Wisconsin glacial boundary is made in the southeastern part of the province, specifically in Bartholomew, Shelby, Decatur, Rush, Franklin, Fayette, and Union counties, because of the fact that here the glacial cover is thin and contains relatively little water bearing sand and gravel, and bedrock formations are more important as aquifers. Ground water supplies are derived from sands and gravels associated with glacial drift and limestones and sandstones of the Paleozoic System. The thickness of the surficial materials varies greatly, and the source of supply in a great many cases depends upon the proximity of bedrock to the surface of the ground. Flowing wells, either in glacial drift or the underlying bedrock strata, are not uncommon. The best ground water supplies are found associated with glacial outwash material such as valley trains, filled valleys, and outwash plains. Waters from bedrock formations or from glacial gravel are generally hard since the most common bedrock aquifer encountered in northern Indiana is Silurian limestone, and the glacial gravels contain a high percentage of limestone pebbles and fragments. Waters from deeper bedrock sources are usually mineralized and, consequently, are not potable.

a. *Lake and Moraine section.* The ground water region designated here as the Lake and Moraine section approximates the Northern Moraine and Lake physiographic region of Malott (2, p. 112-124). It is characterized by a thick blanket of glacial drift which generally exceeds 150 to 200 feet or more. The thickness of the drift in Steuben County is reported to exceed 500 feet. Morainic masses containing much sand and gravel are common. These sands and gravels are the sources of many local supplies of ground water but vary greatly in depth, The areas between the massive morainic masses are frequently occupied by lakes, marshes, and lacustrine plains. In these low areas water supplies

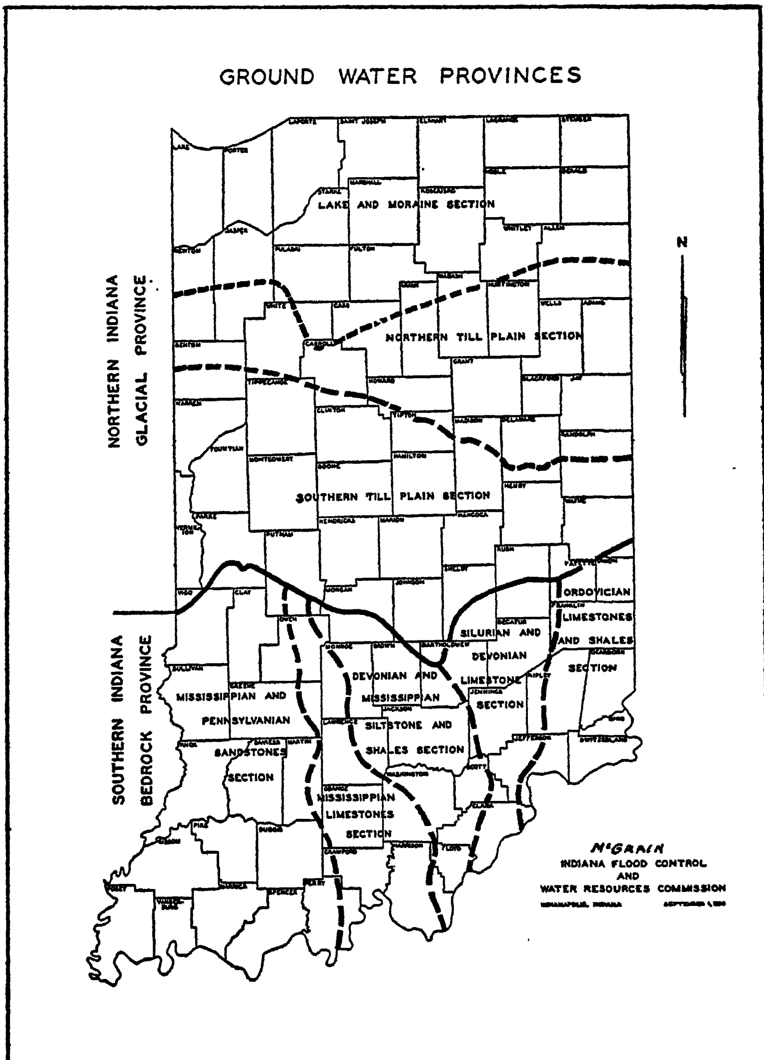

Fig. 1. Map of Indiana showing location of ground water provinces and sections.

are obtained from sands and gravels for domestic and livestock purposes at shallow depths. Great areas of sand are present along the Kankakee, Iroquois, and upper Tippecanoe valleys. Except on the sand hills water supplies are generally acquired at shallow depths from dug wells or from driven well points. Buried bedrock valleys are known to exist along the south-central portion of this area. These channels

usually contain copious quantities of water bearing sands and gravels. Glacial sluiceways and valley trains, particularly along Eel River in Whitley, Wabash, and Miami counties, are excellent sources of ground water.

Locally the glacial drift may be clay till, clay, or marl, and water supplies are difficult to locate. Good supplies of ground water are spotty in parts of Noble, Fulton, and Pulaski counties, Madison and Penn townships in St. Joseph County, and around Black Oak and East Gary in Lake County.

Hammond, East Chicago, Whiting, Gary, and Michigan City depend upon Lake Michigan for public water supplies.

b. *Northern Till Plain section.* As the name implies the Northern Till Plain section is located in the northern part of the Tipton Till Plain physiographic province of Indiana. It is differentiated from the Lake and Moraine section on the north and the Southern Till Plain section by having a relatively thin blanket of glacial drift over a dissected, limestone upland plain. Exposures of bedrock in Indiana in the region of Wisconsin glaciation are not common but are most abundant in the Northern Till Plain section, particularly along the trough-like valleys of the major streams. The section is a slightly modified ground moraine and over wide areas is monotonously flat. The glacial cover over most of the area varies in thickness from 20 to 70 feet and consists primarily of a clayey till. Small isolated pockets of sand and gravel in this till provide insignificant amounts of water for domestic and livestock purposes. The most common source of ground water in the Northern Till Plain section is from the Silurian limestone and dolomite formations which immediately underlie the glacial drift in most of the region. Where the limestone beds are thin or particularly tight the water supplies are poor. In the west central part of the section shales are sometimes found overlying the limestone sequence and have apparently prevented the recharge of the underlying beds.

Although the bedrock formations are generally not far beneath the surface of the ground in this section great local variations do occur in the thickness of the glacial drift. Thicknesses from nothing to more than 450 feet have been encountered. These variations are due primarily to the presence of a former major drainage system, the trunk stream of which was the Teays (=Kanawha). The Teays (=Kenawha) valley is a high level valley which rose in Tertiary time in the Blue Ridge Mountains in North Carolina and flowed west and northwest across Virginia, West Virginia, Ohio, Indiana, and Illinois. It is believed to have discharged into the Gulf Embayment through bedrock valleys now generally occupied by the present Illinois and Mississippi rivers. That portion of the valley in western Ohio, Indiana, and Illinois is buried beneath glacial drift and its route across this area has been traced by means of well records. In Indiana a variety of materials fill the buried channel and its tributaries. In general, however, where the tributaries of the main valley flowed in a southerly direction water bearing sands and gravels are generally present in quantities. On the

other hand where the tributaries of the main valley were north flowing, the valleys are generally filled with fine grained sediments which are poor aquifers.

c. *Southern Till Plain section.* The name Southern Till Plain section is proposed for the southern portion of the Northern Indiana Glacial province. The boundary between the Southern Till Plain section and the Northern Till Plain section is somewhat arbitrary. However, a careful analysis of the sources of public water supplies, as well as supplies in rural and suburban areas, reveal a pattern that can not be ignored. The area is a fiat to gently undulating glacial plain. The trough-like valleys of the major streams and low morainic ridges provide the greatest diversity of relief. The most important sources of ground water in this region are lenses of sand and gravel in the glacial drift and outwash material along the glacial sluiceways. Excellent deposits of water bearing sand and gravel are known to exist along Wabash and White rivers, Fall Creek, and other smaller streams. The average thickness of the glacial materials over most of the area exceeds 100 feet. Maximum thickness is known to be 400 feet or more. Little is known about the character of the bedrock surface except locally. Channels and other irregularities typical of an old erosion surface have been encountered by oil and gas wells and an occasional deep test for water, but little effort has been made to date to obtain a regional picture of an older drainage system. Beds, lenses, and pockets of more or less stratified sands and gravels interbedded in the drift in an uncertain and unsystematic manner provide most of the water supplies.

Where the drift is thin or dominantly clay till, water supplies are spotty and erratic and wells must go to the bedrock formations for adequate supplies. Of the bedrock aquifers in this area, Silurian limestone formations are the most widespread and most reliable. Devonian and Mississippian limestones and the Mansfield sandstone, basal member of the Pennsylvanian in Indiana, yield ground water in the western part of the Southern Till Plain section. Bedrock formations in Fayette, southeastern Henry, and southern Wayne counties, where the section is underlaid by Ordovician formations, are poor aquifers.

II. *Southern Indiana Bedrock province.* The Southern Indiana Bedrock province occupies about 41 percent of Indiana. The boundary between this ground water province and the Northern Indiana Glacial province has already been discussed. Paleozoic limestones and sandstones and glacial outwash materials in the valleys of the larger streams are the most important aquifers. The presence of the variety of bedrock formations in the Southern Indiana Bedrock Province is the result of the structural effect of the Cincinnati Arch, the axis of which passes north-northwest from the vicinity of Cincinnati, Ohio. Strata on the western flank of this uplift dip at an average rate of 25 to 30 feet to the mile toward the synclinal basin in south-central Illinois.

Pockets of sand and gravel in Wisconsin glacial drift carry minor amounts of water and are used only locally for domestic water supplies.

The Illinoian glacial drift is generally a thin, impervious, clay till, and is relatively unimportant as a source of ground water. Also, in this province are numerous filled valleys which may be described as two general types. The first type consists of the valleys which served as discharge routes for glacial melt waters and which contain great thicknesses of water bearing sands and gravels. These valleys are used extensively for public water supplies. The Ohio, Wabash, White, and Whitewater river valleys are but a few examples. The second type consists of the valleys which were blocked by the advancing Illinoian glacier and in this ponded condition were filled largely with lacustrine deposits. Only small supplies of water can be obtained from these fine grained sediments. Bean Blossom, Bridge, McCormick's, and Mill creek valleys are examples of this latter type of filled valley.

That portion of Indiana which was not subjected to glaciation lies wholly in the Southern Indiana Bedrock province. Here ground water supplies are obtained from wells in Paleozoic limestones and sandstones, wells in alluvial sands and gravels, and from springs.

a. *Ordovician Limestones and Shales section.* The Ordovician Limestones and Shales ground water section lies almost wholly within the Dearborn Upland physiographic province. The area is characterized by being the main outcrop area of the Ordovician formations in Indiana. The Ordovician strata are in aggregate about half shales of non-resistant character to weathering, the remainder being rather resistant limestones of a flaggy nature intercalated with the soft shales. These bedrock formations are impervious to downward percolation of meteoric water and can not be considered as potential aquifers for anything except very meager supplies. Waters in the deeper formations are generally mineralized and are not potable.

The entire Ordovician Limestones and Shales section has been subjected to glaciation. In the extreme northern part of the region small quantities of water for domestic or livestock purposes are locally obtained from lenses or pockets of gravel and sand in the Wisconsin drift. The Illinoian drift is thin, varying in thickness from an average of 30 or 40 feet on the north to only a few feet on the south. The Illinoian drift is dominantly till and the water supplies from it are not large.

Some of the valleys, particularly those of the Ohio and Whitewater rivers, were glacial sluiceways and are deeply filled with water bearing sands and gravels. Public water supplies of many communities located along these streams come from these aquifers.

b. *Silurian and Devonian Limestones section.* The Silurian and Devonian Limestones ground water section is that area in southern Indiana in which these geological formations are exposed at the surface of the ground or are but a short distance beneath the surface. These strata are both limestones and dolomites and are the principal aquifers in the region. These formations, where encountered beneath the glacial drift, are reliable aquifers for most domestic and livestock purposes and

for some of the smaller public and industrial uses, but they are generally hard. Water is found in the upper part of the rock strata. Some of the larger cities in the region have had some difficulty in obtaining a sufficient supply from these aquifers to meet the increasing demand for water. Deeply entrenched streams in this region have permitted water in the limestone and dolomite formations to drain away in many cases, thus increasing the difficulty in securing ground water supplies. Springs are frequently found along the steeper slopes but none of these supplies are known to be very large.

Glacial deposits are of sufficient thickness in the northern half of the Silurian and Devonian Limestones section to have water in sand and gravel lenses. These supplies are usually limited to domestic and livestock uses. The Ohio River valley, parts of Muscatatuck River valley and the valleys of some of the other streams have alluvial and fluvio-glacial deposits of sufficient thickness to be important locally.

c. *Devonian and Mississippian Siltstone and Shales section.* The Devonian and Mississippian Siltstone and Shales section is in the main area of outcrop of the Borden Group (Lower Mississippian in age) and the New Albany shale (which has been recognized as both Mississippian and Upper Devonian) of Indiana. The section is characterized by the general absence of ground water supplies throughout the region. The bedrock strata lack both porosity and permeability, lithologic features which are requisite for a good aquifer. A few springs are present in the area but these are relatively unimportant. Silurian and Ordovician water bearing formations which underlie this area at depth generally carry mineralized waters and are not potable.

The most important aquifers are alluvial and fluvio-glacial sands and gravels which are found along the major streams. The valleys of Ohio, White, and Muscatatuck rivers contain copious quantities of water bearing sand and gravel.

Illinoian glacial drift was deposited on an old erosion surface over much of this area. At the present time the drift deposits are thin or absent over large areas. Where the drift is of sufficient thickness, supplies of ground water may be obtained from lenses and pockets of sand and gravel interbedded in the till. These waters are only of local importance and are not known to be adequate for public supplies of any of the larger cities in the section.

d. *Mississippian Limestones section.* The Mississippian Limestones ground water section is in the area of outcrop of the limestone formations in the middle and upper parts of the Mississippian sequence. Most of the area is unglaciated. The several limestone formations which are exposed in this section are the main aquifers. The area characteristically is a karst region with many springs and caves and hundreds of thou--sands of sinkholes. The cavernous condition of these limestone formations permit water to drain away and shallow wells are frequently difficult to obtain. By the same token there is an excellent chance for surface pollution at shallow depths. Water in the limestone is usually

found associated with bedding planes, joints, and other fractures. Occasionally cavities are penetrated which yield an abundant supply of water. The contact between the St. Louis and Salem limestones and the contact between the Harrodsburg and Edwardsville (upper formation of the Borden Group) are usually reliable horizons for securing water supplies. In the western part of this area wells in the Mississippian limestones may yield mineral waters such as those found in the French Lick and West Baden area. Waters encountered below the Mississippian limestones in this section are almost certain to be mineralized.

Natural springs are abundant in the Mississippian Limestones section. They are associated with almost every limestone formation in the area. All of the large springs are outlets of subterranean solution channels, and often serve as the mouths of caves. These waters may come from a short or very long distance and a continued flow through all seasons is dependent upon the size of the gathering area. During most of the year waters discharging from these springs are clear but following heavy rains they yield great volumes of unfiltered, muddy storm waters. In the outcrop area of the Chester (Upper Mississippian) formations the Beech Creek limestone is an important spring horizon, and is characterized by hundreds of springs of excellent water. None of the springs, however, are of large size, being on the order of 10,000 gallons daily.

Only the extreme northern part of the Mississippian Limestones ground water section has been subjected to glaciation. This area is so small that water supply from glacial sands and gravels constitute a very minor part of the ground water resources of the section.

Alluvial deposits in the valleys of the major streams and fluvioglacial fill in the Ohio River valley are water bearing but have not been developed to any extent in the section.

e. *Mississippian and Pennsylvanian Sandstones section.* The Mississippian and Pennsylvanian Sandstones ground water section lies in the southwestern part of Indiana and includes the outcrop area of the coal producing formations and that part of the Chester outcrop area where the main Chester sandstones are buried beneath the surface of the ground. The section is characterized by the fact that sandstone formations are the most widespread aquifers in the area. This is the only ground water section in the state where sandstone aquifers are widespread or used extensively. Although the section is characterized by them, these formations are not always reliable aquifers. Locally any one of the Mississippian or Pennsylvanian sandstones yields a pretty good supply of water, but a particular formation can not be considered dependable, as many of the standstones are known to become shaley or entirely shale down dip from the outcrop. Even the well known Mansfield formation experiences facies changes within very short distances and can not be relied upon to be water bearing everywhere that it may be tested. Waters are also found in joints and fractures of coal formations, but these are generally insignificant. The public water supply for Jasonville in northwestern Greene County is reportedly from a well 10

inches in diameter, 90 feet deep, which penetrates an abandoned coal mine workings of several hundred acres, in which an adequate supply of water is impounded. This water, like all water associated with coal in Indiana, is mineralized; it is potable but not particularly palatable. Where any of the sandstone formations are deeply buried, generally 400 feet or more, the waters can be expected to be saline or otherwise mineralized and not potable. Pennsylvanian limestone formations are not of sufficient thickness to be of any significance for ground water.

The best aquifers in the Mississippian and Pennsylvanian Sandstones section are the sands and gravels associated with the deeply filled valleys of the Ohio, Wabash, White, and Eel rivers.

Many of the tributary streams in this section were blocked by glacial meltwaters flowing down the trunk streams as well as the ice front itself and, as a result, became filled with silts and other fine grained sediments. Occasionally sufficient water bearing sands and gravels are present in the tributary valleys to provide limited supplies of water. Some of these latter valleys are used as sources of public water supplies, even though they are located some distance from the cities they serve.

The Illinoian glacial drift, like that in other parts of the Southern Indiana Bedrock province, is dominantly till. Water supplies associated with pockets or lenses of sand and gravel in the till are of local importance only.

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Manufacturing Level of Manufactural Evansville

BERNARD H. SCHOCKEL, Aurora

The manufacturing level is a revealing and useful ratio. It is, broadly speaking, the percentage ratio of the output to the input. It is not a measure of profits; rather it is a rough indicator of the economic contribution of the factory, an indicator of the relative change effected by the factory.

In an unpublished paper read at the universities of Chicago and Illinois, there was depicted the areal distribution of the manufacturing level in the United States by counties, and thereby was demonstrated a striking areal differentiation in the distribution of the manufacturing level. In this paper there is shown the distribution of the manufacturing level in time (1859-1939) in manufactural Evansville, Indiana, and in selected categories thereof.

There is discernible order in these curves of manufactural Evansville and 25 of its categories as exhibited in the accompanying chart (Fig. 1). Some aspects of this order are presented herein, but an exhaustive analysis is beyond the space limitations of this paper.

Consider for our first example the curve for the category, Cigars. This industry started in Evansville in the 1850's, with two factories in 1860, with 42 in 1899, eleven in 1923 when the dollar volume of the output was nearly eight million dollars (this climax was also the zenith of the industry), and six factories in the early 1930's. About 50 wage earners were employed in 1859, and they mounted to about 180 in 1889; but the number jumped to about 550 in 1899, to about 1900 in 1914, and to nearly 2700 five years later, after which there was a decline to about 1500 as of the early 1930's. In 1859 the manufacturing level was 180, which means that the value added by the tobacco factories was 180 per cent of the value of the tobacco (and fuel and other closely associated items). This is a high level, and indicates much labor and know-how. Note that there followed 1859 (with exceptions) a gradual decline in the manufacturing level to a figure of 109 as of 1937. This gradual decline in the manufacturing level of the cigar industry of Evansville was normal, and it was due to many factors such as increased relative competition, technology, cost of materials and fuel. The major interruption in the smoothness of the curve occurred between 1899 and 1905. The manufacturing level dropped from 161 as of 1899 to 86 as of 1904, although the gross output rose from $259,000 dollar volume to $383,000. (This decline was due in part to an increase in the cost of materials as compared to the selling price of cigars f.o.b., and to an incipient change from numerous small factories to larger factories with an associated increase in facilities, and in output per worker.) There is evidence that the entire curve rose to a level exceeding 180 preceding

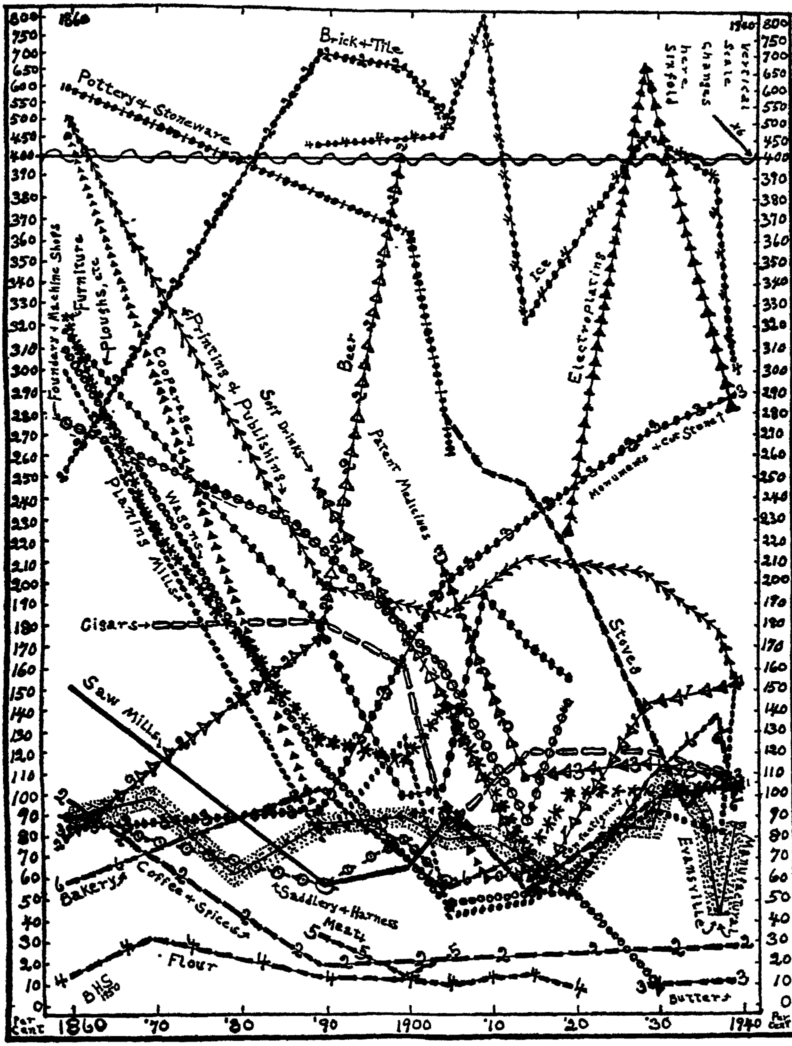

Fig. 1. Manufacturing level of manufactural Evansville, selected categories.

1859. From birth to 1937, therefore, the entire curve is roughly parabolic, with exception. The same is substantially true of the category, Printing and Publishing.

As a matter of fact, the normal curve of a manufactural category tends to be parabolical, with exceptions, though the curve is in many instances masked by various factors and forces. Many cases are not simple. Nevertheless, the recognition of this tendency toward a parabolic curve, and the isolation of the curve, are important, and potential

for analysis, diagnosis, and prediction. In the case of Cigars, the Evansville manufacturing level was lower in recent decades than that of the average for the United States, largely owing to Evansville's location with respect to raw materials versus her location with respect to market. The local industry, therefore, faced some problems. However, the management of at least one of the factories preferred to remain at Evansville because of home ties.

Consider for a second example the curve of the category, Wagons, which category has disappeared, though it persisted in Evansville for more than a century. There were four wagon factories in Evansville in 1837; three in 1890; and one in 1933. The dollar volume of production exceeded two million in 1919, the climax. The manufacturing level declined from 309 in 1859 to 53 in 1919, after which the rate of decline increased bringing the level to nadir, the zenith having been attained prior to 1859. The most striking lowering of this manufacturing level was associated with huge contractual mass-production for a mail order firm, on low-margin profit per unit. In a sense the wagon industry did not perish; it mutated to automobile bodies, ice boxes, Victrola and radio cabinets, refrigerators, etc. This industry is an example of one which ran the gamut from youth, to maturity, to old age and demise; but that is another story.

Consider for the third example the curve of the category, Furniture, which category represents the wood industries of Evansville, where wood dominated manufactural Evansville for decades (1855-1930). There was a cabinet-making establishment in Evansville as of 1836; there were 27 furniture factories as of 1914, since when the number has declined. The gross output reached a climax in 1923 (more than eleven million dollars). The manufacturing level of furniture was 345 in 1859; it declined gradually to 126 in 1899; fluctuated to a nadir of 73 in 1914; and then rose to a plateau of about 100. Outstanding factors in the lowering of the curve were relative increase in competition, technology, and cost of wood, plus mass production on a marginal level of profit per unit, especially for mail order houses. Later the category recovered somewhat, partly by means of an increase in high-price class goods. The chief elements of strength of the extant industry are excellent relative position with respect to hardwoods of the Lower Mississippi, relatively low cost of fuel, skilled labor with wages in keeping with the location of Evansville, and manufactural momentum. Other wood industries, such as Sawmilling and also Cooperage, exhibit similar curves, marking the heyday and relative decline of wood manufactures in manufactural Evansville. Millplaning, however, has rejuvenated, owing largely to veneering, and production of parts and units for buildings.

For the fourth example we may note the curve of the category, Foundry and Machine Shops, as representing Metals. Metals have displaced wood in dominance in Manufactural Evansville. There were three foundries and machine shops in 1856, which number increased to 18 as of 1919, and then declined to eight as of 1932. The climax number of wage earners was in 1919 (1300), which date also marked the climax and

zenith in production (over six million dollars). The manufacturing level of the category was 275 in 1859. It gradually declined to 97 in 1914 due to many factors such as increased relative competition, cost of materials and fuel, technology; increased output per worker; advertisement; and the rise of foundries in the South. Note, however, that rejuvenation set in during the middle nineteen teens, and raised the level to 145 in 1919. Rejuvenation was due in part to World War I, innovations, mutations, a change to higher-price class products, improved freight rates, a shifting of the main market from the South northward, and to influx of capital and management from the East. Note similarity in the curves for Foundries, Ploughs, Stoves—all marking the rise of Metals, now strikingly apparent in the huge factories producing automobile bodies, refrigerators, steel for structures, steam shovels, engines, etc. The outlook for Metals is firm.

The category, Monuments and Cut Stone, presents an instance of inverted parabolic curve. The manufacturing level rose longtime, from 86 in 1859 (when finished stone was rough) to 287 in 1939 in line with highly finished stone, high union wages, much labor on semi-custom work, quasi-fictitious values of tombstones inherent in custom, respect for the dead, pride, etc. Note the low but steady manufacturing level of such foods as flour, meat, and butter (but not of pharmaceutical foods).

Manufactural Evansville has maintained a flattened, plateau-like, strong curve (with exceptions) for the most part slightly higher than the level of average for the United States. This augurs well for her future.

It is apparent that when the manufacturing level of a category continues to fall in comparison with those of its competitors, the category faces problems irespective of dollar volume of output, and current profits; and vice versa. Even the Ford company encountered that fact.

Finally, in analysis of a category other indicators and clues in addition to the device of the manufacturing level must be employed. In conclusion, the device should be studied, corrected, and improved.

Summary

(1) A large majority of the categories net-trend from an early high manufacturing-level to a recent lower level, with a nadir hovering about the dawn of the twentieth century. (2) the rejuvenation of old industries, the mutation of others. The aperiodic appearance of new industries, with high levels, and the death of certain industries with low levels, all tend to rejuvenate the composite curve of manufactural Evansville. (3) Some industries, like ice, and bricks, have maintained a very high level (low cost of fuel and materials; high cost of conveyance by potential competitors). (4) Some industries, like wagons, exhibit a marked drop in manufacturing level (not quality) coincidental with quantity-production for special consumers. (5) The curves tend to be parabolical.

The Natural Gas Industry of Indiana

E. A. STONEMAN, Indiana University

The state of Indiana, with increasing importations of natural gas available through pipe lines, has rapidly expanded its industrial, commercial and residential consumption. Imported natural gas is favored because of its convenience, low cost and an average B.T.U. content of 1050 per cubic foot of imported gas as compared to less than 600 for most manufactured gas and Indiana natural gas. Privately owned A and B state gas utilities dealing mainly in natural gas had a fixed investment of $84 million at the end of 1949, an increase of 9% over 1948[1] with increased valuation mainly in natural gas installations. Total gas revenues for Indiana reached slightly over $40 million divided as follows: natural gas 53%, manufactured gas 30%, mixed manufactured and natural gas 16%, and liquid petroleum gas less than 1%. Indiana among the states ranks 15th as a consumer of natural gas and 20th as a producer, as well as ranking 20th in reserves.

Data on this industry are available from several reports (1, 2, 3).

Production

The first gas well drilled in the state was in Delaware County in 1876 and foreshadowed a sizeable industrial development between 1886 and 1905 with the drilling of additional wells. Cities such as Muncie, Marion and Anderson owe their early importance in glass manufacturing to these local gas supplies which, however, soon proved inadequate and were supplemented by manufactured gas and later by natural gas piped from West Virginia. Projects to supply large amounts of natural gas from local sources have not been successful for more than a short period of time although attempts were made by a pipe line from Greentown to the Calumet region and from Pike and Gibson Counties to Evansville. To the present time over 9000 gas wells have been drilled in the state with a total recorded production of over 550,000 million cubic feet, but proven reserves at the present time are only 25,200 m.c.f. Thus even though 30 new wells were drilled in 1949 and many wells in older fields are still producing, the amount of state natural gas consumed is insignificant when compared with the total imported.

Most towns and communities dependent on local gas have obtained standby facilities or are in the process of doing so as service cannot be maintained satisfactorily during winter months. Most of the towns still without standby facilities are located south and southeast of Indianapolis with major users in Henry, Rush and Decatur Counties. A large part of the gas supply is concentrated around Rushville and Vincennes but total

[1] All statistics are for 1948 unless otherwise indicated.

production is decreasing rapidly. The 1949 production of 625 m.c.f. is about 7000 m.c.f. below the total for 1906 and 2875 m.c.f. under the peak wartime production of 1941.

Manufactured gas is produced in large quantities principally in Terre Haute and Indianapolis, but with the completion of a pipeline now being constructed between the latter city and Zionsville both cities will have supplementary supplies of natural gas available for mixing. Seven of eight other towns and cities with facilities for making manufactured gas also have natural gas facilities. There are 17 liquid petroleum gas plants in the state of which 16 use propane gas and one butane, but these are in general used for standby facilities except in four cases where natural gas supplies are unobtainable.

Transmission and Distribution

The first major supply of natural gas imported into Indiana came by pipeline from West Virginia in 1913, but by 1918 the supply was far short of demand and manufactured gas began to supply most of the gas needs of the northeast counties. The Kentucky Natural Gas Company (whose transmission lines are now operated as the Texas Gas Transmission Company) in 1931 built a transmission line into Indiana to Evansville and later extended it to Terre Haute to connect with the Panhandle Eastern Pipeline Company and serve the southwest and south central parts of the state. Also in 1931 the Panhandle Eastern Pipeline Company, which obtains its supplies from the Hugoten and Panhandle fields, completed a transmission line to Dana, Indiana, near the Illinois state line, which pipeline has become the major supplier of imported gas for Indiana. Lines were built to serve northern Indiana while the old West Virginia transmission lines (purchased in 1942) were connected to the aforementioned company's pipelines which are supplied by two 24 inch pipes (Fig. 1).

The Calumet District in 1938 made connection with the Chicago District Pipeline Company, which obtains its supply from the Texas Panhandle Field, and the supply continues to be used for mixing with natural gas or for an interrupted supply in the north and northwest areas. The Louisville Gas and Electric Company transports gas into southern Indiana for use in Jeffersonville, New Albany and Corydon.

In 1946 the United States Government agreed to transport natural gas on its Big Inch and Little Big Inch lines, originally constructed to transport gasoline, to meet fuel shortages. Two years later this line was purchased by the Texas Eastern Transmission Corporation which contains two pipes, of 24 and 20 inch diameters, entering Posey County in the southwest corner of the state and leaving through Franklin County in the southeast. A line of the Texas Gas Transmission Corporation crosses the southeast corner of the state, serving Madison and Lawrenceburg before continuing into Ohio. In the northwest the Michigan-Wisconsin Pipeline Company serves the northwest corner of the state through the Northern Indiana Public Service Company.

Thus Indiana has six major suppliers of imported natural gas, with

about 60% of the supply coming from Texas, and next in order of importance are Kansas, Oklahoma, Kentucky and Louisiana. Indiana

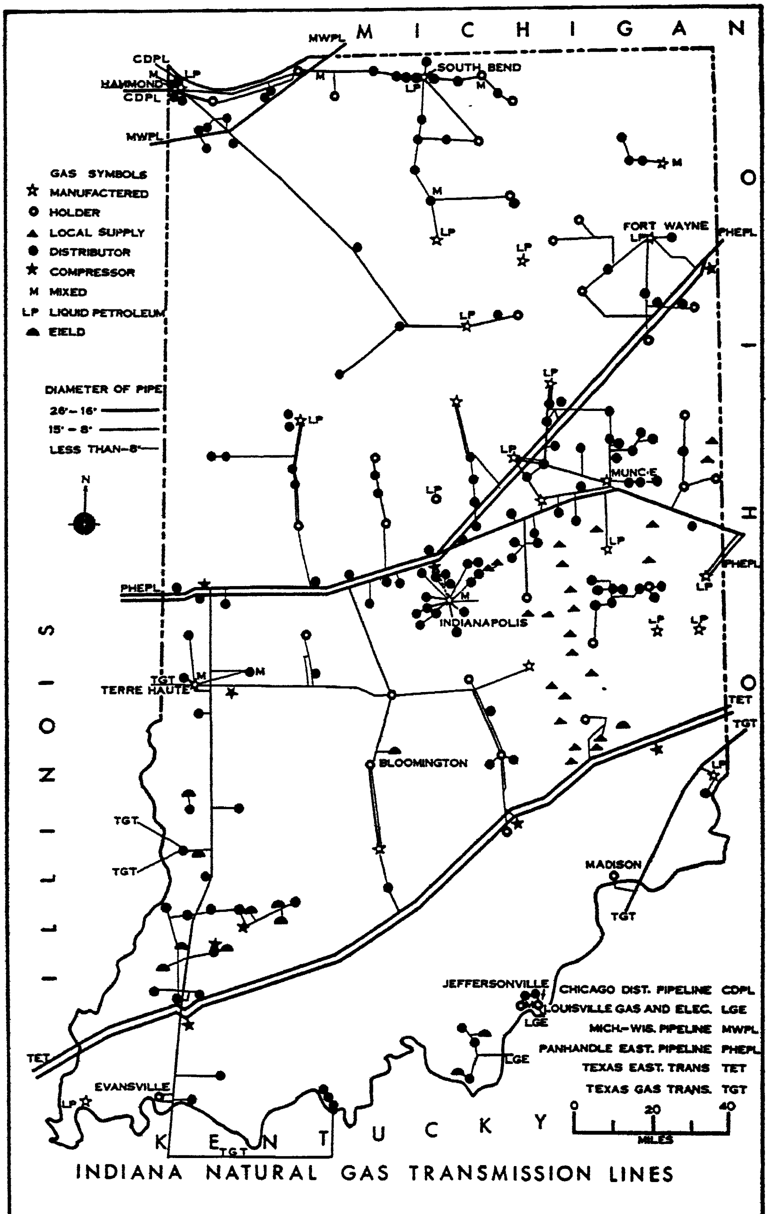

Fig. 1. Transmission lines for natural gas in Indiana.

exports small amounts of gas into Illinois where location along the boundary warrants it. Indiana has 8,630 miles of all types of pipeline divided as follows: 4,900 miles for natural gas, 2,700 for manufactured gas, 970 miles for mixed and 60 for liquid petroleum gas. The natural gas pipelines were utilized as follows: 2,950 miles for distribution, 1,830 for transmission, and 120 for field and gathering. Many of the gas utilities are associated with electrical utilities while there are 25 major distributors of natural gas in Indiana in addition to municipal units.

Sales and Utilization

The consumption of natural gas has increased from 5,904 m.c.f. in 1933 to 38.885 m.c.f. in 1948, or an increase of 85% during the 15 year period, while estimates for 1949 and 1950 indicate a continued rise. Manufactured gas although continuing a steady growth in consumption has lagged far behind natural gas in rate of increase, as during the same period manufactured gas increased from 9,061 to only 15,848 m.c.f. or an increase of 43%. Mixed gas has also shown a spectacular increase to almost 10,000 m.c.f. per year while liquid petroleum gas, especially popular in residences, is rapidly becoming an important fuel.

Industry was by far the greatest single consumer of natural gas, using 25,161 m.c.f. or 64% of the total as compared to 28% for domestic and 8% for commercial and other users. However, of a total revenue of $21,320,000 industry despite being the largest consumer of natural gas accounted for only 39% of the sales revenue, which was possible through preferential consumption rates. The number of customers is dominated by residential users, approximating 93% of the total, while less than 1% was industrial. The number of natural gas customers in the 15 year period to 1948 has increased 41% to 230,000 whereas the number of manufactured gas customers has decreased slightly to approximate those of natural gas.

Gas sales are largest during the winter months when residential requirements are at a maximum. A great difference in heating degree days[2] exists between the northern and southern parts of the state with 6203 for Ft. Wayne and 4405 for Evansville, so that allocations of gas supplies are generally more critical in the north during cold winters.

According to average index numbers, using 1935-1939 as a base, the cost of gas and electricity actually decreased to 1948 adding to its popularity, whereas all items had an increase of 73% and food and clothing increased over 100%. Another factor which accounts for the rapid increase of supply and consumption of natural gas for Indiana and the United States as a whole is reflected in the higher net incomes of natural gas utilities as compared to those of manufactured gas. Thus the net income for natural gas utilities in the United States showed a 15% profit, mixed gas 9.8%, and manufactured gas only 4.8%, while

[2] One degree day is counted for each degree of deficiency for every day on which a deficiency occurs—using 65° as the base temperature.

natural gas distributing utilities had a 10.4% profit as compared to 18.5% for transmission utilities.

Conclusions

Indiana has a shortage of natural gas while distribution is not adequate in some parts of the state. In recent years new sources for importing natural gas have been utilized while compressor stations have increased pumping pressures, but demand still exceeds supply. Thus especially in the northern parts of the state industrial development has in some cases been hampered and restrictions continue on residential gas consumption.

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HISTORY OF SCIENCE

Chairman: M. G. MELLON, Purdue University

R. E. Girton, Purdue University, was elected chairman for 1951.

ABSTRACTS

The charter members of the Indiana Academy of Science. WILL E. EDINGTON, DePauw University.—The facts as now known regarding the charter membership list of the Indiana Academy of Science are presented. New evidence was uncovered by Dr. John S. Wright in the "Indiana Pharmacist" for January, 1886, in which the names of forty individuals were listed as charter members of the Academy.

A list of 69 members considered as charter members is included.

The Indiana Physician as geologist and naturalist. W. D. INLOW, Inlow Clinic, Shelbyville.—In 19th century the physician played a great role in development of natural science. This is no longer true. Science in Indiana begins in New Harmony. David Dale Owen and the first geological survey 1837-1838. Biographical notes concerning chief physicians interested in geology and natural history are presented with comments concerning their contributions: Asahel Clapp, 1792-1862; John T. Plummer, 1807-1865; Ryland T. Brown, 1807-1890; Rufus Haymond, 1805-1886; W. T. S. Cornett, 1805-1897; Alembert Winthrop Brayton, 1848-1926; Moses N. Elrod, 1838-1907; Arthur John Phinney, 1850-1942; Marcus Ward Lyon, Jr., 1875-1942.

Some contributions by scientists from Indiana State Teachers College and Rose Polytechnic Institute.[1] JAMES F. MACKELL, Indiana State Teachers College.—A great many of the contributions by scientists from Indiana State Teachers College and Rose Polytechnic Institute have already been listed in other volumes of the proceedings of the Academy. However, some of the more recent contributions have not been listed. An attempt will be made in this paper to point out some of the contributions made by such outstanding scientists as Roscoe Hyde from Indiana State, Herald Cox from Indiana State, and Professor Johonnott of Rose Polytechnic Institute, and others. No attempt will be made to make an exhaustive report at this time. However, contributions other than the ones listed above will be incorporated in the report.

Developments in analytical balances. M. G. MELLON, Purdue University.—The equal arm balance is said to represent the most significant contribution of the alchemists to modern science. Actually, this instru-

[1] This paper will appear in the forthcoming volume "Indiana Scientists."

ment can be traced to a period seeming to antedate anything recognized as alchemy.

Without fundamental change in design it came into the 20th century. The last few decades, however, have brought very significant changes. In general, they have been directed toward achieving greater speed in weighing and in facilitating the operation. Significant examples are multiple riders, key-board manipulation of weights, chain weights, vernier riders, damping, projection reading scales, and constant sensitivity mechanisms.

This trend toward indicating instruments is a step, of course, in the direction of the ultimate in balances—one which will weigh 100 grams to four decimal places and record the value.

Thomas Say, Entomologist, in Indiana. B. ELWOOD MONTGOMERY, Purdue University.—Thomas Say first saw Indiana in 1819, when he passed down the Ohio River from Pittsburgh to St. Louis as zoologist on Long's expedition to "explore the Missouri and its principal branches—." Although several thousand insects were collected, of which hundreds were new to science on the expedition it is doubtful if many were collected during the passage down the Ohio. However, four years later, Say again came to Indiana; as Zoologist and Antiquary on Long's "Expedition to the Source of St. Peter's River," he traversed the state in traveling, according to orders from the War Department, from "Wheeling in Virginia, thence to Chicago via Fort Wayne." Few, if any, of the specimens of insects obtained in the state during this trip are recorded for Indiana, as Say was never very specific in his locality records.

Say came to New Harmony in "The Boatload of Knowledge" in 1826 and made his residence there until his death in 1834. His entomological studies were continued during this period, although many of the species obtained on the western trips had already been described. It may be questioned if Say found these years of his life very happy, living far removed from centers with libraries and museums, directing the work of school boys, serving as editor or even printer, and acting as McClure's business agent in the quarrels and law suits following the break up of the Owen community. However, he continued to make some collecting trips, and to receive letters and published papers from correspondents in the East and in Europe; and he wrote a dozen papers on insects, three of which were not published until after his death. Furthermore, the care of McClure's affairs may not have burdened him too heavily as he never seemed to have let his own property or business interests interfere with his scientific studies, and he refused an offer of work in New York at one time.

Johnny Appleseed (John Chapman) in Indiana. C. L. PORTER, Purdue University.—The name and deeds of Johnny Appleseed have become legendary throughout the Eastern portion of the United States. Attempts to separate facts from fiction pose difficult problems to the historian. It would seem that Chapman was born in Massachusetts. He emigrated to Ohio at an early age and at a time when Ohio was

still a wilderness. In his later years he moved farther westward to Indiana and according to the most authentic evidence died in Allen County near where Fort Wayne is now located.

The facts associated with the life and demise of Johnny Appleseed in Northern Indiana are obscure and have constituted the basis of bitter controversy.

The puzzling and confused data that have caused argument are presented in this paper.

An analysis of Rumford's methods of testing the Eighteenth Century theories of heat. DUANE ROLLER, Wabash College.—Rumford's experiments on heat, particularly those on heat produced by friction (1798), have been examined to determine the general method of attack employed, and their role in the development of the dynamical theory of heat. Many writers, including Joule and Tyndall, appear to have misinterpreted or overlooked the significance of Rumford's work in one or more important respects.

Some outstanding science students from Shortridge High School. FRANK B. WADE.[1]—A brief biographical summary is presented for each of the following twenty-three scientists who received their high school education at Shortridge in Indianapolis: H. H. Bartlett, J. R. Schramm, M. Fishbein, H. F. Dietz, E. P. Stevenson, A. B. Hastings, I. H. Page, H. A. Howe, S. A. Cain, P. D. Bartlett, J. H. Payne, J. Paitt, R. F. Daubenmire, F. M. Baumgartner, W. W. Davis, W. H. Hoskins, R. M. Cavanaugh, W. D. Billings, R. K. Jennings, W. A. Daily, D. S. Van Fleet, B. Vonnegut, C. N. Rice. The list is chronologically arranged according to graduation dates.

[1] Deceased. See page 25 for memorial.

Analytical Chemistry in the United States, 1830-1850

WARREN W. BRANDT, Purdue University

The period between 1830 and 1850 was a witness to a great advancement in the field of chemistry. During this period there occurred a profound change in the position of chemistry as an individual science. The greater part of the advancement was due to the European chemists, who were the leaders in the field at that time; however, the American chemists made their own definite contribution to this growth and development.

The advances were made equally in the theoretical and practical aspects of the science, as well as in the educational field. By necessity, analytical chemistry was a leader at this time. The chemist of the day was dealing with the unknown, and in order to establish anything he had to turn to the analytical approach. It is quite reasonable, therefore, that the analytical chemists should stand out as some of the important leaders.

The following discussion is an attempt to give recognition to a few of the outstanding analytical chemists of the period, and to compare their conditions and techniques to ours. Undoubtedly many men whose contributions are also noteworthy have been omitted from this short discussion. The men discussed are a few of those whose publications in the volumes of the *American Journal of Science* lend confirmation of their prominence. Some of the biographical material has appeared in the *Amercan Chemist.* **(1).**

The equipment with which these men labored leaves much to be desired when compared to that which is now available. Their lack of chemical glassware, burners, and other simple pieces of common laboratory equipment makes their circumstances seem primitive by comparison. They relied heavily upon blowpipe analysis and frequently considered a smell test as sufficient proof for positive qualitative detection. Counterpoised filter papers were combined for a filtration, and after the precipitate had been dried in the paper, the individual pieces were separated, one again serving as the counterpoise. Washing of a precipitate frequently required 12 hours and the drying of a precipitate on a sand bath was sometimes continued for days.

Many of their procedures are very similar to current ones. A double dehydration of silica with hydrochloric acid was common technique, as was the precipitation of calcium as the oxalate. The methods of precipitation of iron, aluminum, and magnesium were very similar to ours. This list could be extended to many other techniques common to both periods.

The activities of the analytical chemists fall into two distinct categories; general and special. These categories develop quite naturally

from the fact that some men occupied themselves with complete analyses of samples, whereas others were interested mainly in some specific analysis or determination. Such a classification gives a nearly equal division of the work done.

The "general" classification embodies analyses of mineralogical, coal, meteoric, coral and agricultural samples. That such a large proportion of the activities of the time should be devoted to this type of work is quite understandable in the light of the fact that the expansion and exploration of the United States was still the major national endeavor. It seems logical that the analyses necessary to support the numerous geological surveys and investigations initiated during that period should be a very important contribution of chemistry to its environment.

One of the outstanding mineralogists of the day was Charles Upham Shepard whose "Treatise on Mineralogy" was a handbook for many years. Dr. Shepard, who was located at the Medical College of the State of South Carolina, contributed much to the analytical chemistry of the times with his numerous publications containing minerological analyses.

At the same time, Augustus A. Hayes had obtained a reputation as an outstanding analyst, and his works appear in collaboration with geologists and mineralogists who brought their samples to him for analysis.

Charles T. Jackson also contributed much to this literature. He contributed even more to analytical chemistry when he founded the first laboratory for instruction in analytical chemistry in Boston in 1838.

The list of men recording complete analyses would be long, and would include the following men and their interests: Walter Johnson, coal; Benjamin Silliman, Jr., coal and coral; John C. Norton, Lewis C. Beck, and Robert Peter, agricultural.

The classification of "special" work includes many interesting developments by American chemists. The interests of the group are widely varied, ranging from the use of special reagents to the refinements of analytical technique as it was known at the time. In many cases the developments were meant to be aids to the performance of complete analyses; which, whether published results appear or not, represented the major field of activity of the analytical chemist for reasons outlined above. In many cases we find men contributing to both categories.

Dr. Charles Jackson belongs to the latter group. In addition to the work already mentioned, he was interested in the detection of arsenic, particularly in connection with poisoning. In his discussion of the Marsh test, he mentions obtaining a sensitivity of one part per million, an exceptionally good test for that period. The detection of gold is also included in a list of his interests.

Dr. J. Lawrence Smith, whose current reputation is due to his method for the decomposition of silicates and subsequent determination

of the alkalies, received his M.D. degree and became a leader in the field of chemistry during this twenty year period, although his above-mentioned work did not appear until somewhat later. Working in Charleston, South Carolina and abroad, his interests were many and varied. He early reported the use of potassium chromate as a reagent for barium in the presence of strontium. His investigation included a search for a reagent to selectively dissolve the precipitates, and as a result he obtained a confirmatory test for barium if the precipitate did not dissolve in acetic acid. This desire for a greater certainty in qualitative testing exemplifies one phase of the development of the scientific thinking of the period. He followed this type of work in showing the use of CaF_2 as a test for fluoride ion rather than the usual etching of glass. In the early forties Dr. Smith became interested in the action of neutral salts on each other. He investigated many examples and presented theories for their explanation.

Perhaps Dr. Smith's article most interesting to analytical chemists is his 1843 contribution concerning a new instrument for the analysis of carbonate-containing materials. In this he describes with accompanying drawings a vertical glass tube with a portion graduated from 0-100 from bottom to top. The lower end of the tube is drawn out into a tip. Entitling this tube a "calcarimeter", he proceeds to describe in minute detail the procedure one should follow in making an acid solution and standardizing it against a sample of a pure carbonate. This is followed by details for evaluating an alkaline solution against the standard acid, and the subsequent procedure for diluting each solution in order to give a concentration which will give a more convenient reading. The necessary steps for the determination of an unknown carbonate sample are then described. Again these are done in minute detail. He even describes another tube with only three calibrations which was used for adding the excess acid. The third calibration is designed for adding an additional portion of acid in case one goes past the litmus paper end point.

It is of interest that Dr. Smith controlled the flow by placing a cork containing a glass tube in the top of the buret and regulating the addition with his finger in the manner in which we now use a pipet. He also demonstrated his modern insight by his discussion of the fact that his procedure had the further advantage that it could be performed with good accuracy by untrained personnel. He even includes data obtained by persons who had no training and were told just which steps to follow.

This investigation did not show whether this is the first buret described in the literature, but it seems to be one of the first applications of our present day "back-titration". Dr. Smith was well versed in the chemical literature of the day. He served for some years as a foreign correspondent for the *American Journal of Science* while he was in Paris, and he did considerable abstracting of foreign articles for the same journal. It seems quite reasonable that a man who was a leader in his field and so well informed in his field would not have gone into

such detail to describe the instrument, the preparation of the standard solutions, and the procedures involved if they were not new. His other articles do not follow such a pattern.

Many advances in classical analytical technique were due to the efforts of William B. and Robert E. Rogers. These two brothers came from a family in which the father and four sons were all active in the field of chemistry. The two mentioned made much more of a contribution to analytical chemistry than the others, however. Initial evidence of their interest in carbonates was shown in a paper dealing with an improved instrument for the determination of carbonate: a weighed system in which the flask, acid, and samples were weighed prior to mixing and after evolution of carbon dioxide. This article in 1844 was followed in the next two years by others which dealt with an application of the instrument to the study of the decomposition of minerals and rocks by carbon dioxide-containing waters and the absorption of carbon dioxide by solutions.

Their works are all characterized by an outstanding insight into the errors involved. They were meticulous in their dedication to detail. They pointed out to the leading German chemists that they were ignoring a serious error due to adsorbed water vapor in the system, and therefore used thorough drying trains in conjunction with their experiments. They considered the errors due to adsorption of gas by the corks and the fallacy of handling the apparatus with bare hands. They suggested that the work should be done at a constant temperature so that wiping of the apparatus was not required, since electrostatic charges were developed in so doing. These few examples only serve to represent the nature of their valuable contribution to chemical experimentation techniques, and to illustrate the advance in the thinking of the time. It was this line of thought which contributed greatly to the change of chemistry from a philosophy to a science.

Professor W. W. Mathers at West Point contributed to the chemistry of the day with the determination of the ratio of the constituents in aluminum chloride and aluminum oxide. In the latter he pointed out to Berzelius that his values were incorrect and that his ratio was the inverse of the true one. He also presented a unique determination of silver in an ore following cupellation. He worked from a standard curve relating the size of the globule and the amount of silver.

Professor Robert Hare at the University of Pennsylvania was undoubtedly one of the most energetic thinkers of the period. The literature at that time is full of his letters to Berzelius, Faraday, and other leaders concerning points in their current theories or interpretations with which he could not agree. His development of new apparatus for the analysis of air and the purification of carbon monoxide carried him into the analytical field.

One could easily extend this reminiscing to volumes, but this consideration will terminate with having mentioned only a few of the better known men. Professor J. W. Bailey deserves mention for his insight into qualtitative analysis as early as 1837. The first few para-

graphs in his communication deal with the way in which reagents function. He defined, but left unnamed, the functions "selective" and "specific". The addition of these terms would make his writing appropriate in any modern text. Dr. Lewis Feuchtwanger did some very early work on the reactions of arsenic; which, accompanied by a number of colored illustrations, stands out in the 1830 literature.

Having considered the men, their thinking and works, there remains one rumination which binds the whole together; education. Chemistry in 1830 was not an entity. It was not taught as an individual science. It is reasonable that in view of the prominence of analytical chemistry, the analytical chemist should have a great deal to do with the development of instruction of chemistry. Thus, Dr. Jackson's laboratory of instruction in Boston in 1837. Also Benjamin Silliman, Jr., a student of Jackson, and Joseph P. Norton founded in 1847 what became known as the Yale Analytical Laboratory. It is significant that although this laboratory was conducted in a Yale University building, the founders paid rent to the University for its use; and they furnished from their own private funds all expenses for equipment, supplies, and salaries connected with the operation of the laboratory.

That such conditions should have been a part of our educational history is unfortunate. However, the advances made by the analytical chemists of the period did much to hasten the acceptance of chemistry as a science which deserved recognition in our educational system. The following tribute to an analytical chemist has appeared in the literature (1): "The Massachusetts Institute of Technology owes the conception and successful inauguration among science teaching institutions of America almost solely to the personal efforts of Professor William B. Rogers".

In these many ways, analytical chemists and analytical chemistry, as yet unrecognized as such, contributed to the development and recognition of the science of chemistry between 1830 and 1850.

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The First Printed Picture of Indian Corn

PAUL WEATHERWAX, Indiana University

The purpose of this note is to correct, or at least to question, an oft-repeated statement about the first publication of a picture of the Indian corn plant. The point is not one of great importance, but if any statement about it is worth making at all, it is worth while to see that it is correct.

The earliest appearance of the error was apparently in Miall's work on the early naturalists (2). In his account of Oviedo he says (p. 63) that this early Spanish chronicler was the first to publish figures of many American plants, including Indian corn. Later historical works have made the same statement, the context often indicating that they got the idea from Miall.

In a recent work on the literature of maize, Finan (1) treats the question in a way which is likely to continue the error. He gives a conspicuous place to the alleged first figure, stating that it comes from an early Italian edition of Oviedo's work, but he gives no definite citation or other source of his information. In a footnote a little farther along (p. 159) he says that he has examined the first Spanish editions of Oviedo and found no figure of maize. A review of the facts as now known leads us to the conclusion that this figure was not the first published.

Gonzalo Fernández de Oviedo y Valdés was one of the colorful personalities of the period of the Spanish conquest of America. Brought up in the royal household of Spain as a companion for the young prince John, he was present, at the age of fifteen, at the impressive court reception given by Ferdinand and Isabella for Columbus on his return from the first voyage to America; and in the ensuing years he heard first-hand the accounts of the New World brought back by the explorers. In 1514 he was sent to Santo Domingo as inspector of mines and supervisor of gold smelting. He returned to Spain on a visit in 1523 and, before his death in 1557, made five more round-trips to America and wrote extensively of his experiences.

While he was in Spain in 1523, his account of what he had seen in the New World elicited so much interest that he hurriedly prepared for the king a summary of a longer manuscript which he had left behind him in Santo Domingo. This *Sumario* was published in Spain in 1526. The first part of the longer work, the *Historia General y Natural de las Indias,* was published in 1535, and there was another Spanish edition in 1547. Other editions followed, but the complete work was not published until 1851.

A few years ago I had the good fortune to examine the first edition of the *Sumario* and the second edition of the *Historia General* in the

Bancroft Library of the University of California and the first edition of the latter in the Huntington Library at Los Angeles. There is no figure of maize in any of them. The *Sumario* has five woodcuts and the longer work some 25 or 30. Various native or introduced plants of the New World, such as the cactus, pineapple, mamey, fig, yucca, banana, and two kinds of manioc, are shown, but no corn. It seems almost certain, therefore, that as late as 1547, Oviedo did not include a figure of maize in any of his publications.

There are two remote possibilities that this conclusion might not be correct. The first is that there may be other editions of which we have no knowledge; but the literature of the period has been so thoroughly catalogued that this seems unlikely. The second possibility is that a figure might have been included in some copies of an edition and not in others. In those days, changes were sometimes made during the printing of a book so that the finished copies were not all identical in content; but to make such an assumption in this case, without some positive evidence, would seem to be taking a long chance.

Meanwhile, the first edition of Fuchs' famous herbal came out in 1542, and his excellent figure of maize seems to have a clear title to the record of being the first to appear in print in any publication anywhere. A copy of this was published in the Proceedings of this Academy in 1945 (3).

The second edition of Ramusio's *Navigationi et Viaggi*, published in 1554, includes the figure copied by Finan—apparently the one which caused the confusion. Whether this figure was included in the first edition (1550) has not been determined, but this is beside the point since either edition is antedated by Fuchs.

Anyone who examined only Ramusio's Italian edition of 1552 and found there the figure of maize might conclude that it, along with the others, had been carried over from the earlier editions of Oviedo's work. That may be the source of the error. A closer examination of the figures, however, shows that that of maize is not in the same style as the relatively crude ones of Oviedo.

When Ramusio was preparing the second edition of his book of travels, feeling the need of an illustration of this spectacular plant to accompany Oviedo's work, he simply "lifted" one from one of the current herbals. The herbal of Matthiolus (edition of 1565) has the same figure, but in reverse; and it will be recalled that copying figures in reverse was a common practice in making woodcuts, when there was no essential difference between a picture and its mirror image. Who made the original drawing and where it was first published have not been determined, but it did not appear in some of the earlier editions of Matthiolus, the earliest of which bears the date of 1544.

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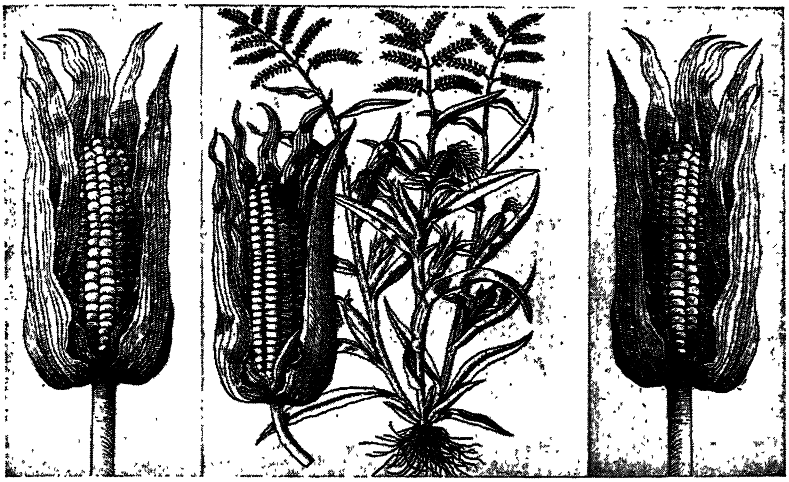

FIG. 1. Early figures of maize. Right, the figure from Ramusio. Left, the same printed in reverse for comparison with Matthiolus' figure (middle), from which it seems to have been copied.

MATHEMATICS

Chairman: W. H. CARNAHAN, Purdue University

V. Hlavaty, Indiana University, was elected chairman for 1951

ABSTRACTS

On the line-space interpretation of the differential geometry of curves in Klein space. L. K. FRAZER, Indiana University.—The Plücker coordinates of a line are six numbers which satisfy a projectively invariant quadratic equation. This yields at once the obvious mapping from the lines in ordinary space to points of a four-dimensional quadric, called the K-quadric, which lies in a five-dimensional linear space, called K-space. (Klein-space).

This paper utilizes the above mapping together with the polarity in K-space induced by the K-quadric and the polarity in three-space induced by a linear complex to find the interpretations in three space of the invariants of a K-curve. Interpretations of such projectively invariant properties as the minimal linear imbedding space and the degree of a K-curve and some examples such as K-conics are considered.

The results obtained have the advantage of reducing the differential geometry of these higher dimensional space curves from one of abstract analytic descriptions to one which can be easily visualized.

The notation involved and basic definitions of the Line-geometry follow that of the book, "Differentielle Liniengeometrie" by Dr. V. Hlavatý.

Skepticism and the fifth axiom of Euclid. VACLAV HLAVATY, Indiana University.—The noneuclidean geometry may be thought of as a geometry whose underlying group is a special subgroup of the general projective geometry. The corresponding representation is particularly fit to point out the failed "proofs" of the fifth axiom of Euclid, as well as the ideas of Lobachevski. The paper finishes with the Beltrami realization of the noneuclidean geometry.

Equations with cyclic Galois groups. RALPH HULL, Purdue University.—An outstanding unsolved problem of the Galois Theory is that of determining equations with prescribed groups. (N. Tschebotarow, Commentarii Mathematici Helvetici, Vol. 6 (1934), pp. 235-283; in particular § 2). A related problem is that of determining extension fields with prescribed groups of automorphisms relative to a given ground field. For abelian groups the latter problem falls within the scope of the class-field theory. In particular, when the ground field is the field of rational numbers, the abelian extension fields are cyclotomic fields, that is, subfields of fields of nth roots of unity. The present paper is

a preliminary report of an exploratory nature on a method of attacking the first mentioned problem by way of the class-field theory for the rational ground field.

A testing program for freshmen mathematics students in Valparaiso University. C. O. PAULEY, Valparaiso University.—Purpose of the Testing Program: To ascertain preliminary knowledge as to the abilities of entering-freshmen mathematics students; to "screen out" the weaker ones and provide remedial measures for improving their mathematical skills. Test was administered to *Liberal-Arts* freshmen who intended to enroll in MATHEMATICS 51 (Algebra and Trigonometry). "Failure" on the test did not bar a student from enrolling in beginning mathematics course. Those making a very low score were requested to enroll in a remedial course of three hours *concurrently* with the regular four-hour course.

Results of Test Administered in September, 1950: 78 freshmen were given the test. It consisted of 24 items in algebra—13 items on "Computational Skills", 11 items on "Numerical Reasoning", (Multiple-Choice Type).

Mean score	11.65.
Range of scores	3 to 22.
Standard Deviation	4.47.

12 of the 78 students (approximately 15%) made a score of 7 or less. These were requested to enroll in the remedial class. Others may enter during the semester whenever it is thought advisable.

Future Procedure: The final semester grades in Mathematics 51 will be observed and compared with the grades made on the preliminary test.

A similar test will be given at the close of semester work in algebra (approximately 11 weeks devoted to algebra) and comparisons made with preceding grades.

A note on continuity. J. CRAWFORD POLLEY, Wabash College.—The customary definition of the continuity of a single valued function of a variable x as x varies over the interval (a, b) does not express the fundamental analytic concept of continuous variation associated with the Cartesian graph of the function. The equivalence is not so apparent as the majority of textbooks seem to indicate. Because of the importance of the concept good teaching demands that the equivalence be explicitly demonstrated. This paper presents such a demonstration. Based on the customary definition of continuity over a closed interval (a, b) and the division of the interval into sub-intervals over each of which the function is increasing, decreasing, or constant, it is shown that the conditions for continuous variation are satisfied.

A hydrodynamical corollary of Julia's Theorem. JAMES B. SERRIN, Indiana University.—The purpose of this note is to present a short and easy proof of an important theorem in hydrodynamics first stated in 1938 by the Russian mathematician, M. Lavrentieff.

Consider two curves S'_1 and S'_2 on the closed Riemann sphere, passing through 0 and ∞ and having common tangents at these points. We may suppose the tangent at ∞ is 0. Let S_1 and S_2 be the images of S'_1 and S'_2 in the z-plane, and let D_1, D_2 be the plane infinite regions bounded respectively by S_1 and S_2 and containing the point $-i\infty$. In addition let D_1 contain D_2. Consider two steady irrotational flows of an ideal fluid, one occupying D_1 and the other occupying D_2, and suppose that both flows have the uniform velocity U at infinity. Let V_1, V_2 be the velocities of the flow at 0 in the regions D_1, D_2, respectively.

Theorem. With the suppositions above,

$$V_1 \geqslant V_2,$$

and the equality holds if and only if S_1 is identical with S_2.

Numerous applications of this theorem may be given. I shall confine myself to presenting one very simple one, and to indicating certain others.

Variant of the Theorem of Humbert. DAVID E. VAN TIJN, Indiana University.—An answer will be provided to this question

1. For which paths defined in a parameter t by elementary functions is the arc length an elementary function of t?

A generalization of Descartes' Rule of Signs. EUGENE USDIN, Purdue University.—Various generalizations of Descartes' Rule of Signs have been established to determine the number of zeros of a polynomial in parts of the complex plane other than the real axis, and to treat polynomials with complex coefficients. They have in common the estimation of the number of zeros by means of the number of changes of sign or argument in the sequence of coefficients. In this paper the following generalization is established:

The number p of zeros of the polynomial $a_0+a_1 z+\ldots+a_n z^n$ in the sector $|\arg z| \leqslant \gamma$ is given by the formulae

$$p=\left\{\frac{2n\gamma}{\pi}\right\}-\left\{\frac{n\gamma}{\pi}\right\}+\mu-2k \qquad \text{if } n\gamma \not\equiv \frac{\pi}{2}\ (\pi)$$

where μ is the number of changes of sign in the sequence

$$\left\{a_0, a_1 \cos\gamma, \ldots, a_n \cos(n\gamma)\right\}$$

and k is a non-negative integer.

$$p=\left\{\frac{n\gamma}{\pi}\right\}+\nu-2k' \qquad \text{if } n\gamma \not\equiv o\ (\pi)$$

where ν is the number of changes of sign in the sequence

$$\left\{a_0, a_1 \sin\gamma, \ldots, a_n \sin(n\gamma)\right\}$$

and k' is a non-negative integer.

On the impossibility of the trisection of an angle. NELSON P. YEARDLEY, Purdue University.—By giving a counter-example, we show that it is impossible to trisect all angles.

First we establish the proposition that it is impossible to construct a line whose length is a root of a cubic equation with rational coefficients having no rational root. Then we show that to construct a 60° angle we must construct a line whose length is the root of the equation

$$x^3 - 3x - 1 = 0$$

which has no rational roots.

A Method of Visualizing Four Dimensional Rotations

JOHN KRONSBEIN, Evansville College

Three dimensional (XYZ) space with rectangular coordinates may be radically projected upon a unit sphere in 4 dimensional ($x_1x_2x_3x_4$) space by means of the formulae

$$
(1) \qquad
\begin{aligned}
x_1 &= \frac{X}{[R^2+X^2+Y^2+Z^2]^{1/2}} & \qquad x_2 &= \frac{Y}{[R^2+X^2+Y^2+Z^2]^{1/2}} \\
x_3 &= \frac{Z}{[R^2+X^2+Y^2+Z^2]^{1/2}} & \qquad x_4 &= \frac{R}{[R^2+X^2+Y^2+Z^2]^{1/2}}
\end{aligned}
$$

The unit sphere S_4 in four-space may then be stereographically projected upon spherical 3-space with (xyz) coordinates by means of the formulae

$$
(2) \qquad
\begin{aligned}
x_1 &= \frac{2Rx}{R^2+x^2+y^2+z^2} & \qquad x_2 &= \frac{2Ry}{R^2+x^2+y^2+z^2} \\
x_3 &= \frac{2Rz}{R^2+x^2+y^2+z^2} & \qquad x_4 &= \frac{R^2-x^2-y^2-z^2}{R^2+x^2+y^2+z^2}
\end{aligned}
$$

These formulae (2) are the generalization of the standard formulae for stereographic projection, and it is seen that the coordinates (xyz) represent a set of parameters for the unit sphere S_4.

Combination of (1) and (2) yields the relations

$$
(3) \qquad \frac{R\,x}{X} = \frac{R\,y}{Y} = \frac{R\,z}{Z} = \frac{R^2-x^2-y^2-z^2}{2R} = \frac{R^2}{R+[R^2+X^2+Y^2+Z^2]^{1/2}}
$$

and

$$
(4) \qquad x = \frac{X}{R+[R^2+X^2+Y^2+Z^2]^{1/2}}; \qquad y = \frac{Y}{R+[R^2+X^2+Y^2+Z^2]^{1/2}};
$$

$$
z = \frac{Z}{R+[R^2+X^2+Y^2+Z^2]^{1/2}}.
$$

The rotations of the four-dimensional sphere S_4 constitute the group of (proper) quaternary transformations of the variables ($x_1x_2x_3x_4$) that are linear and homogenous and whose coefficient matrix $A=[a_{ik}]$ is orthogonal: $AA' = 1$, the dash meaning transposition of rows and columns of the matrix. The relations (1) show that they induce linear *fractional* transformations of the quantities (X/R, Y/R, Z/R) with coefficients which are components of the corresponding quaternary

orthogonal matrix. These transformations are

$$\frac{X}{R}=\frac{a_{11}X'+a_{21}Y'+a_{31}Z'+a_{41}R}{a_{14}X'+a_{24}Y'+a_{34}Z'+a_{44}R};\qquad \frac{Y}{R}=\frac{a_{12}X'+a_{22}Y'+a_{32}Z'+a_{42}R}{a_{14}X'+a_{24}Y'+a_{34}Z'+a_{44}R};$$

$$(5)\qquad \frac{Z}{R}=\frac{a_{13}X'+a_{23}Y'+a_{33}Z'+a_{43}R}{a_{14}X'+a_{24}Y'+a_{34}Z'+a_{44}R}.$$

It would have been possible to use homogeneous coordinates instead of (XYZ); then the quaternary orthogonal transformations of S_4 would have induced the same transformations of these, but for a factor; the geometrical significance that follows below would, however have been less apparent.

The transformations (5) have the property that they leave invariant the quadric $R^2+X^2+Y^2+Z^2$ which may be regarded as fundamental quadric for the establishment of a metric in the (XYZ) space. Since this is a positive definite quadratic form, the metric must be elliptic. The (XYZ) space subject to the group of transformations (5) therefore has an elliptic metric impressed upon it.

The relations (2) show that the quaternary orthogonal transformations of $(x_1x_2x_3x_4)$ also induce a group of transformations in spherical (xyz) space. These are

$$(6)\qquad x=\frac{2a_{11}x'+2a_{21}y'+2a_{31}z'+a_{41}(R^2-x'^2-y'^2-z'^2)}{2a_{14}x'+2a_{24}y'+2a_{34}z'+(a_{44}+1)R^2+(1-a_{44})(x'^2+y'^2+z'^2)}$$

$$y=\ldots\ldots\ldots$$
$$z=\ldots\ldots\ldots$$

with similar expressions for y and z. They are clearly not linear, and in fact are easily shown to be inversions. The coefficient matrix A does not, however exhaust the inversion group in (xyz) space, since the fundamental invariant of the operations (6) is $R^2+x^2+y^2+z^2$. The group which leaves this expression unchanged is called the spherical group, a subgroup of the full (proper) inversion group that has the property of transforming socalled diametral points into similar points. Diametral points are pairs of points lying upon euclidean straight lines through, and separated by, a fixed point O, and so that the product of their (euclidean) distances from O is R^2.

The transition from the spherical (xyz) space to the elliptic (XYZ) space is by means of the formulae (4) which were obtained through the medium of the unit sphere S_4 in four space. The use of four dimensional space can however be avoided by projecting stereographically every plane through O upon a sphere of radius R with O as center; then moving the sphere at right angles to this plane by a distance R; then radically projecting the sphere back again upon the same plane. In this manner diametral points are brought to visible coincidence as shown in Fig. 1. The identification of diametral points represents the conversion of spherical to elliptic space, and it is this transition together with the use of special coordinates (XYZ) in the (xyz) space that permits the visualization of four dimensional rotations.

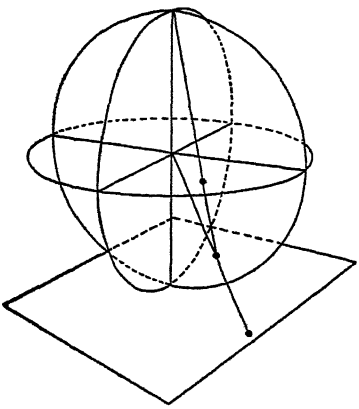

Fig. 1

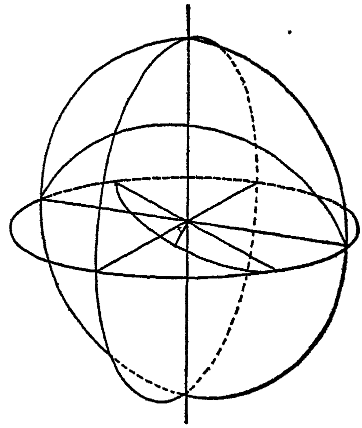

Fig. 2

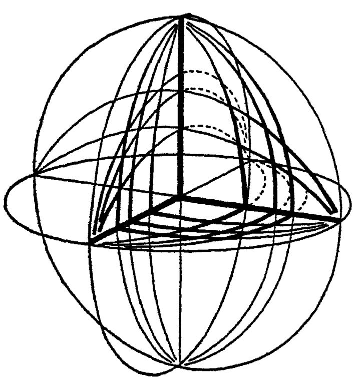

Fig. 4

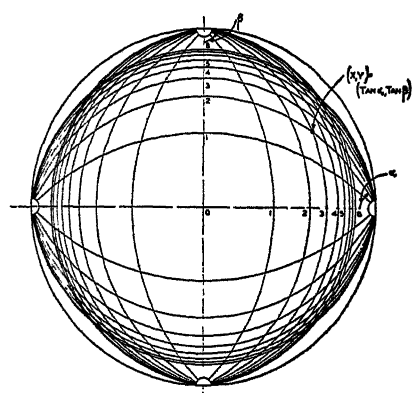

Fig. 5

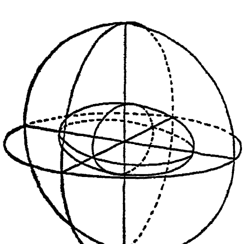

Fig. 6

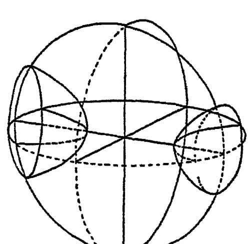

Fig 7

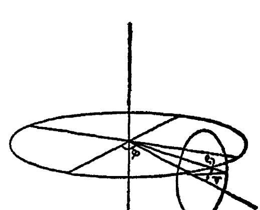

Fig. 8

Great circles on the unit sphere S_4 in 4-space are mapped by this procedure upon circles in (xyz) space through diametral points, and therefore also diametrically opposite points of the sphere S_R of radius R and center O in this spherical space, or upon euclidean straight lines through O. (The latter are special circles in (xyz) space). Fig. 2 shows that non-intersecting circles through diametrically opposite points of S_R are linked. As these are the images of non-intersecting great circles upon S_4, this property of the great circles on S_4 becomes intuitive.

Elliptic planes are mapped upon spheres through great circles on S_R, and the original (XYZ) coordinates which were rectangular, map upon a triple set of circles terminating in the ends of Cartesian coordinates axes on this sphere. Fig. 3 shows a plastic model of the (xyz) coordinate planes with the images of the original (XYZ) coordinates scribed upon them. Fig. 4 shows a perspective drawing of the

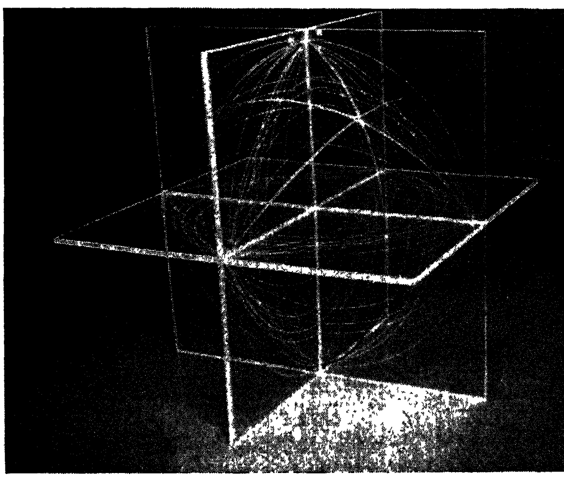

Fig. 3. Plastic model of the coordinate planes (See text).

same set of lines (circles) and Fig. 5 shows the new coordinates in the (XY) plane. The correlation between the numbers and the coordinate lines, by means of the tangent relationship given here indicates that the sphere S_R assumes the rôle of an "infinitely distant" plane. The great circles on S_R assume the rôle of "infinitely distant" straight lines on the "infinitely distant" plane. Now there are no such entities as "infinitely distant" lines points or planes in elliptic geometry so it will be preferable to denote these by the adjective "inaccessible' and thus speak of an "inaccessible line" lying in an "inaccessible plane". Actually, the elliptic distance between two points ($X_1Y_1Z_1$) and ($X_2Y_2Z_2$) is given by

$$d_{12} = \text{arc cos} \frac{R^2+X_1X_2+Y_1Y_2+Z_1Z_2}{[R^2+X_1^2+Y_1^2+Z_1^2]^{1/2}[R^2+X_2^2+Y_2^2+Z_2^2]^{1/2}}$$

so that the "inaccessible plane" has an elliptic distance of $\pi/2$ units of length from the origin, the point O.

The coordinate lines are seen to meet in a point on the inaccessible plane and thus give the impression of being parallel lines similar to what is considered parallel in the euclidean space. But it should be observed that they do not possess the property of euclidean parallels that the intercepts on the set of common normals are of equal length. Upon expansion of S_R so that $R \longrightarrow \infty$, they degenerate into euclidean parallels, and therefore will be referred to as "parallels of the first kind". The reason for the term "first kind" will appear below.

There are only two shapes of (real) quadrics in elliptic space, the hyperboloid of two sheets and the ellipsoid being essentially identical. Algebraically this follows from the inertia property of quadratic forms, but in the present model of the elliptic space it is easy to see the reason. In Figs. 6 and 7 are seen respectively the ellipsoid and the hyperboloid of two sheets. Owing to the identity of diametral points the ellipsoid in Fig. 6 must comprise another circuit outside S_R and inverse with respect to it. Now effect a transformation of the spherical group which transforms the (euclidean) plane that halves the ellipsoid into S_R The left half of the ellipsoid then becomes the right hand sheet of the hyperboloid in Fig. 7. The other sheet is obtained from the outer circuit of the ellipsoid. In two dimensions, bicircular quartics behave in analogous manner (2), and assume the rôle of (sphero-) conics there. Algebraically, these shapes correspond to the following quadratic forms reduced to principal axes:

$$X^2+Y^2+Z^2+R^2=0 \quad \text{(imaginary quadric)}$$
$$X^2+Y^2+Z^2-R^2=0 \quad \text{(oval quadric)}$$
$$X^2+Y^2-Z^2-R^2=0 \quad \text{(ring shaped quadric).}$$

That the second and third quadrics should differ from one another is obvious on grounds of connectivity alone. In euclidean space these connections between the different configurations are not so easily surveyed.

If the transverse generating circles of a torus intersect S_R at right angles, the torus represents a hyperboloid of revolution of one sheet. Fig. 8 shows one transverse generating circle being taken around the equator circle of S_R. The equation of the torus is seen to be

(7) $x = (a+\rho\cos\psi)\cos\phi;\ y=(a+\rho\cos\psi)\sin\phi;\ \ z=\rho\sin\psi,$
where $a^2=R^2+\rho^2$. Elimination of ψ and ϕ yields

$$\frac{\rho^2 \quad (4x^2+4y^2)}{[R^2-x^2-y^2-z^2]^2} - \frac{4R^2z^2}{[R^2-x^2-y^2-z^2]^2} = 1$$

By formulae (2) this immediately transforms to

$$\text{(8)} \qquad \frac{X^2+Y^2}{R^4/\rho^2} - \frac{Z^2}{R^2} = 1,$$

which proves the statement. The quadric (8) in elliptic space is a quartic surface in inversion space (spherical space). The reguli of this so-called *Clifford* surface are elliptic straight lines, euclidean circles in inversion space, oblique generator circles of the torus illustrated in

Fig. 9 and the plastic model shown. There is a *left* and a *right* regulus, but only one is shown. Which of the two is denoted by left and which by right, is of course immaterial.

The entire elliptic space can be filled with Clifford surfaces with a common generator axis, corresponding to increasing radii of transverse generator circles. By consideration of individual sets of reguli it is seen that the surfaces can be generated by translation of points along either "right" or "left" regulus lines. During such a translation a "right" slides along a "left" regulus, or a "left" along a "right" regulus to generate the torus. Such a movement is called a "Clifford Translation". All points in the elliptic space move along elliptic straight lines during such a translation.

In euclidean space any two non-intersecting straight lines have either one common normal or an infinite number of them, and in the latter case the straight lines are called "parallel". In elliptic space two elliptic straight lines have either *two* common normals or an infinite number of them, and in the latter case the intercepts of the normals between them are of equal elliptic length. This means that two such lines are equidistant in elliptic measure, and that is exactly the distinctive property of the reguli of a Clifford surface. Such lines are called "Clifford Parallels" in view of the resemblance to euclidean parallels they bear in respect of distance. Eduard Study (3) called them "paratactics" and distinguished "right" and "left" paratactics, according as two such lines belonged to one or the other set of reguli of a hyperboloid of one sheet (the lines would of course be suitably oriented—reference to this will be made below). The designation "paratactics" is more suitable than "parallels" because upon indefinite expansion of S_R so that $R \longrightarrow \infty$, the parallels of the first kind described above become euclidean parallels, but the Clifford Parallels do not. It is appropriate, therefore to name the Clifford parallels "of the second kind".

Given any two elliptic straight lines, L_1, L_2, it is possible to find a transformation of the elliptic space (and hence also of the spherical model) which carries the intersection of one of them, L_2, say, and one of the common normals of L_1, L_2, into the fixed point O and at the same time to transform the elliptic plane determined by the normal and L_2 into a euclidean plane. L_2 will then be a euclidean straight line (as well as elliptic), and the same applies to the common normal. L_1 will be represented by a circle through diametrically opposite points of S_R Fig. 10 shows this configuration in such a position that the common normal (of L_1 and L_2) is transformed into the z-axis (which is also the Z-axis) while L_2 is a euclidean straight line passing through diametrically opposite points of the equator of S_R (which represents an inaccessible line). If in this configuration the angle $\alpha = \beta$, the two lines L_1 and L_2 are Clifford parallels, and they will then have an infinite number of common normals, the elliptic length of the intercepts between them having the common length α. It will be noticed that unless two straight lines are Clifford parallels, the intercepts on the two common normals are not equal in elliptic length.

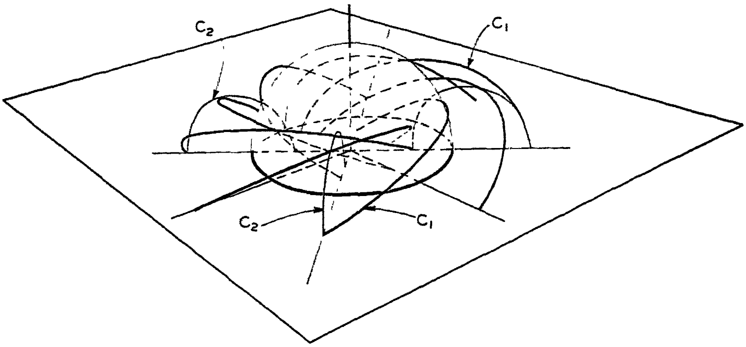

Fig 9

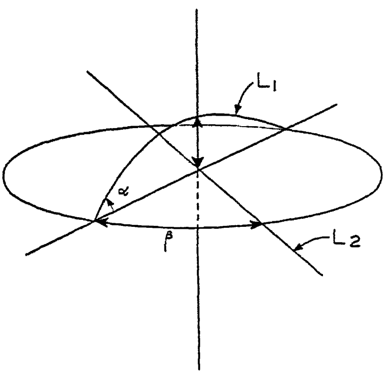

Fig 10

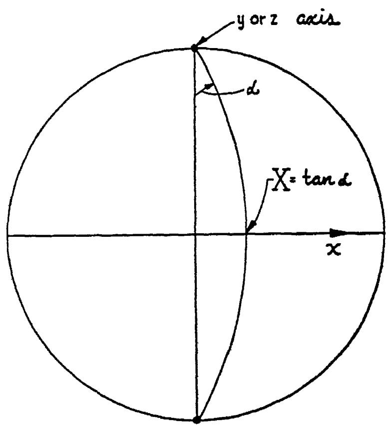

Fig. 11

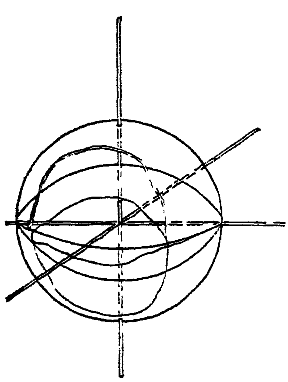

Fig. 12

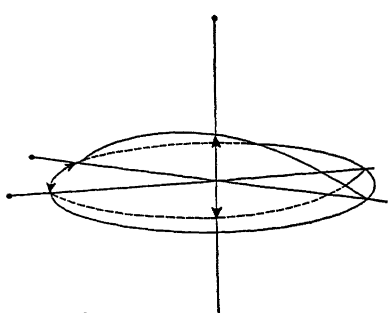

Fig. 13

Another example of a pair of Clifford parallels visible in Fig. 10 is the limiting case where $a=\pi/2$, represented e.g. by the Z-axis and the equator circle. Such a pair of special paratactics or Clifford Parallels will be called a *Study Line cross*, being a generalization of what Study called a "line cross" (3) namely, a straight line in the finite part of (euclidean) space and that inaccessible (infinitely distant) line which crosses it at right angles. In our case a general Study Line Cross will be represented by a pair of circles lying in (euclidean) planes orthogonal to each other and having one (and consequently infinitely many) shortest distance of length $\pi/2$. The line cross will be used in the development of the kinematics below.

If in the transformation formulae (6) the following special coefficient values are inserted:

$a_{11}=a_{44}=\cos a$; $a_{14}=-a_{41}=\sin a$; $a_{22}=a_{33}=1$, and all other coefficients zero, the matrix $|a_{ik}|$ is seen to be still orthogonal, and (6) becomes (8)

$$\begin{aligned} x' &= [2\cos a\, x + \sin a\,(R^2 - x^2 - y^2 - z^2)]/N \\ y' &= 2y/N \\ z' &= 2z/N, \end{aligned}$$

where

$N = -2\sin a\, x + R^2\ (1+\cos a)\ +\ (1-\cos a)\ (x^2+y^2+z^2)$. This transformation will be called a "pseudorotation" about a circle of radius R lying in the (yz) plane, when considered in the spherical or inversion space. It leaves invariant the circle $y^2+z^2=R^2$ in the (yz) plane, which represents an inaccessible line in the inaccessible plane S_R in the elliptic space. It will be seen from Fig. 11 that the plane determined by the y and z-axes has been rotated through an angle a, and this transformation may be generated by a reflection (inversion) in a sphere making an angle ½ a with the (yz) plane, followed by a reflection in the origin, i.e. $x'=-x$, $y'=-y$, $z'=-z$.

The rotations of 4-space now become visible as kinematics in elliptic (XYZ) space or spherical (xyz) space, in either case representable by our spherical model illustrated in Fig. 3. The transformation (8) can be illustrated by Fig. 12 which shows how a euclidean plane through O is transformed into a spherical shell through the equator circle (elliptic plane passing through inaccessible line represented by equator circle.) The 6 "simple" rotations of Cartan's "biplan" are seen to be on the one hand, euclidean rotations of the planes (xy), (xz) and (yz), and on the other the elliptic rotations about inaccessible lines represented by circles of radius R in the (yz), (xz) and (xy) planes, respectively. The last three are obviously pseudorotations in the sense defined above. These relations are shown in Table I, which shows the quaternary orthogonal matrices corresponding to these in the second column, and the geometrical significance in the fourth and fifth columns.

Fig. 13 shows the mechanism of a rotation as well as of a pseudorotation.

The third column in the table shows what becomes of the matrices in the second for angle of rotation or pseudorotation of $\pi/2$. These matrices are commutative with respect to multiplication and certain pairs of them multiplied together yield the 4 x 4 matrices used by Gibbs to represent quaternion units (1). Thus

TABLE I. The Six Simple Quaternary Orthogonal Matrices.

Matrix Symbol	Matrix	Corresponding 90° Rotation	Significance in 4-space	Significance in elliptic or inversion 3-space
M_{12}	$\begin{matrix} \cos\alpha & -\sin\alpha & 0 & 0 \\ \sin\alpha & \cos\alpha & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$	$\begin{matrix} 0 & -1 & 0 & 0 \\ +1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$	Rotation in (x_1x_2) plane	Elliptic *and* euclidean Rotation in (xy)-plane
M_{13}	$\begin{matrix} \cos\alpha & 0 & -\sin\alpha & 0 \\ 0 & 1 & 0 & 0 \\ \sin\alpha & 0 & \cos\alpha & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$	$\begin{matrix} 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ +1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$	Rotation in (x_1x_3) plane	Elliptic *and* euclidean Rotation in (xz)-plane
M_{23}	$\begin{matrix} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha & 0 \\ 0 & \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$	$\begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & +1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}$	Rotation in (x_2x_3) plane	Elliptic *and* euclidean Rotation in (xz)-plane
M_{14}	$\begin{matrix} \cos\alpha & 0 & 0 & -\sin\alpha \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \sin\alpha & 0 & 0 & \cos\alpha \end{matrix}$	$\begin{matrix} 0 & 0 & 0 & -1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ +1 & 0 & 0 & 0 \end{matrix}$	Rotation in (x_1x_4) plane	Elliptic Rotation *about* inaccessible line in inaccessible plane. Line represented by unit circle in (yz) plane.
M_{24}	$\begin{matrix} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha & 0 & -\sin\alpha \\ 0 & 0 & 1 & 0 \\ 0 & \sin\alpha & 0 & \cos\alpha \end{matrix}$	$\begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \\ 0 & +1 & 0 & 0 \end{matrix}$	Rotation in (x_2x_4) plane	Elliptic Rotation *about* inaccessible line in inaccessible plane. Line represented by unit circle in (xz) plane.
M_{34}	$\begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \cos\alpha & -\sin\alpha \\ 0 & 0 & \sin\alpha & \cos\alpha \end{matrix}$	$\begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & +1 & 0 \end{matrix}$	Rotation in (x_3x_4) plane	Elliptic Rotation *about* inaccessible line in inaccessible plane. Line represented by unit circle in (xy) plane.

$$M_{12}(\pi/2) \text{ x } M_{34}(\pi/2) = i = \begin{vmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \end{vmatrix}$$

$$M_{13}(\pi/2) \text{ x } M_{24}(\pi/2) = j = \begin{vmatrix} 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{vmatrix}$$

$$M_{23}(\pi/2) \text{ x } M_{14}(\pi/2) = k = \begin{vmatrix} 0 & 0 & 0 & -1 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{vmatrix}$$

The most general transformation of XYZ space is one which carries an elliptic straight line into another one. The first may be arbitrarily chosen and the latter then preassigned. It is possible to lay an elliptic plane through the given line and one of the common normals, and then to carry out a pseudorotation about that inaccessible line which joins points where the given line and the common normal chosen pierce the inaccessible plane. This pseudorotation is carried out so that the line and the normal have their intersection in the fixed point 0 after the operation. These two lines are then both euclidean and elliptic and they therefore appear as in Fig. 10, and they will be Clifford parallels if $\alpha = \beta$. The given line L_1 may now be moved into the other L_2 by first carrying out a euclidean rotation through the angle β, and following this by an elliptic rotation through an angle α about the inaccessible line crossing the axis of the euclidean rotation at right angles. This pair of operations, i.e. rotations carried out successively about two lines

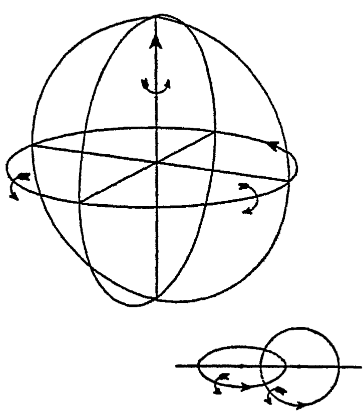

Fig. 14

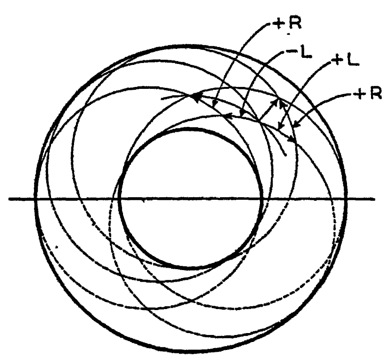

Fig. 15

of a Study Line Cross is commutative: the elliptic pseudorotation about the inaccessible line could have been carried out first, and this followed by the euclidean rotation about the euclidean axis.. Thus, but for a transformation of the spherical group placing the two lines into a special position in the space, the given line is moved into the other by a euclidean rotation about a euclidean axis, followed by a pseudorota-

tion about an inaccessible axis orthogonal to the first. Or, also, *the most general movement in elliptic space consists of the succession of two (elliptic) rotations whose axes form a Study Line Cross.*

It will be obvious that the orthogonal rotations in four-space corresponding to these operations in elliptic or spherical space will decompose in an analogous manner.

The pseudorotation leaves invariant a single infinity of toruses namely those whose common generator axis is the axis orthogonal to the pseudorotation. Individual transverse generator circles of each torus remain invariant as a whole. Thus, this movement is identical with that of a smokering revolving within itself, and is frequently called a "vortex motion".

The decomposition of the quaternary rotations into two, about skew circles on S_4 is not the most elementary one. Each rotation may be seen to be composed of two Clifford translations. It is not difficult to show that the straight lines of the elliptic space may be oriented so that the (arbitrarily chosen) *right* regulus together with the common axis of rotation form a right handed screw in the conventional sense, and the *left* will then be *eo ipso* oriented so that it together with the same axis of rotation, whose orientation remains unchanged, form a left hand screw. Diagrammatically this is illustrated in Fig. 15 where the common axis of the hyperboloids is thought of as directed out of the plane of the paper towards the observer, and a positive right as well as a positive left, generator direction are indicated. The generator circles are imagined collapsed into the plane as circles.

It is now immediately visible that a euclidean rotation about the common axis of composed of a *negative left* Clifford translation, followed by a *positive right* Clifford translation. Similarly, it is seen that a pseudorotation is composed of a *positive left* followed by a *positive right* Clifford translation.

All the preceding geometrical relations, interesting as they are, become increasingly signficant in view of the last statement. For, it is now possible to correlate without trouble the kinematics in elliptic or spherical space with the algebraic expressions for quaternary orthogonal transformations. It is well known that the general (proper) quaternary orthogonal transformations may be represented by the quaternion formula

(9) $|A|\ |B| X' = \bar{A} X B$, where the A, B, and X are quaternions:

$$A = ia_1 + ja_2 + ka_3 + a_4; \quad |A| = [a_1^2 + a_2^2 + a_3^2 + a_4^2]^{1/2}$$

and smilarly for B, X, and X'. $\bar{A}$ is the conjugate quaternion, obtained from A by using —i, —j, —k instead of the positive units.

It is also known that with this representation, euclidean rotations may be expressed as

(10) $|A|^2 X' = \bar{A} X A$

and the expanded expressions then form the *Euler-Rodriques-Cayley*

parametric representation of the ternary orthogonal matric elements. These are shown in table 2, where it should be observed that

$$a_1^2+a_2^2+a_3^2+a_4^2$$

is the denominator of the other nine elements when the matrix is used to express the ternary orthogonal transformations.

It is then not difficult to show that the expression

(11) $|A|^2X'=AXA$

is a pseudorotation about the inaccessible line that crosses the axis of the euclidean rotation $\bar{A}XA$ orthogonally, i.e. the second elliptic line of a Study line cross. The angle of this pseudorotation equals that of the corresponding euclidean rotation. These statements may be proved in two ways, either by direct calculation, or by first transforming the inaccessible line which forms the axis of the pseudorotation into the Z-axis. This converts the pseudorotation into a euclidean rotation about the Z-axis, and the proof is then obvious.

Further, one can then *see* that a transformation such as $|A|X'=AX$ may be correlated to a positive left translation, while $|A|X'=\bar{A}X$ then represents a negative left translation, both in the Clifford sense. Simi-

TABLE II. Parametric Representation of Rotations and Pseudorotations

General Quaternary Rotation $|A|\,|B|X'=\bar{A}XB$; $A=ia_1+ja_2+ka_3+a_4$
Euclidean Rotation $B = A$: $|A|^2X' = \bar{A}XA$
Euler-Cayley-Rodrigues Coefficient Matrix:

$$\begin{matrix}
a_1^2-a_2^2-a_3^2+a_4^2 & 2(a_1a_2-a_3a_4) & 2(a_1a_3+a_2a_4) & 0 \\
2(a_1a_2+a_3a_4) & -a_1^2+a_2^2-a_3^2+a_4^2 & 2(a_2a_3-a_1a_4) & 0 \\
2(a_1a_3-a_2a_4) & 2(a_2a_3+a_1a_4) & -a_1^2-a_2^2+a_3^2+a_4^2 & 0 \\
0 & 0 & 0 & a_1^2+a_2^2+a_3^2+a_4^2
\end{matrix}$$

Pseudorotation $|A|^2X' = AXA$. Axis of this is inaccessible line crossing orthogonally axis of above Rotation.

$$\begin{matrix}
-a_1^2+a_2^2+a_3^2+a_4^2 & -2a_1a_2 & -2a_1a_3 & -2a_1a_4 \\
-2a_1a_2 & a_1^2-a_2^2+a_3^2+a_4^2 & -2a_2a_3 & -2a_2a_4 \\
-2a_1a_3 & -2a_2a_3 & a_1^2+a_2^2-a_3^2+a_4^2 & -2a_3a_4 \\
+2a_1a_4 & +2a_2a_4 & +2a_3a_4 & -a_1^2-a_2^2-a_3^2+a_4^2
\end{matrix}$$

TABLE III. Matrix of Coefficients for General Quaternary Rotation.

$|A|\ |B|X' = \overline{A}XB$ in quaternion notation

$a_1b_1-a_2b_2-a_3b_3+a_4b_4$	$a_1b_2+a_2b_1-a_3b_4-a_4b_3$	$a_1b_3-a_2b_4+a_3b_1-a_4b_2$	$a_1b_4+a_2b_3+a_3b_2+a_4b_1$
$a_1b_3+a_2b_4+a_3b_1+a_4b_2$	$a_1b_4-a_2b_3+a_3b_2-a_4b_1$	$-a_1b_1-a_2b_3+a_3b_3+a_4b_4$	$-a_1b_2+a_2b_1+a_3b_4-a_4b_3$
$a_1b_2+a_2b_1+a_3b_4+a_4b_3$	$-a_1b_1+a_2b_2-a_3b_3+a_4b_4$	$-a_1b_4-a_2b_3+a_3b_2+a_4b_1$	$a_1b_3-a_2b_4-a_3b_1+a_4b_2$
$-a_1b_4+a_2b_3+a_3b_2-a_4b_1$	$a_1b_3+a_2b_4-a_3b_1-a_4b_2$	$-a_1b_2+a_2b_1-a_3b_4+a_4b_3$	$a_1b_1+a_2b_2+a_3b_3+a_4b_4$

larly, $|A|X'=X\overline{A}$ is a negative right translation, and $|A|X'=XA$ is a positive right translation.

The coefficient matrix for a pseudorotation is shown in the lower part of table 2; it is the parametric representation of a vortex motion. When these parameters are inserted in (6), the motion is in inversion space. The geometrical meaning is also easy to deduce, since the significance of the Euler-Rodrigues-Cayley parameters is well known. Thus, $a_1:a_2:a_3$ is known to represent the ratio of direction cosines of the rotation (or pseudorotation) axis, while $-a_4/[a_1^2+a_2^2+a_3^2]^{1/2}$ cotangent of half the angle of rotation.

Table 3 shows the coefficient matrix of a general quaternary orthogonal transformation. When the radius of S_R is made to increase indefinitely, there results a parametric representation of *all* euclidean movements, i.e. rotations as well as translations.

A difficulty arises here, however, inasmuch as the representation is in terms of 8 homogeneous parameters with bilinear composition. The totality of euclidean movements only depends upon 6 essential constants, so that we have one excess constant.

Eduard Study (2) showed that there is no representation in terms of 7 homogeneous parameters with bilinear composition for the totality of euclidean movements, and he assumed that the expression $a_1b_1 + a_2b_2 + a_3b_3 + a_4b_4 = 0$. Study deduced his result by the aid of Clifford dual numbers, i.e. complex numbers $a + eb$ for which a and b are real numbers while e is a unit for which $e^2 = 0$. The totality of euclidean movements is then expressible in the following form using Biquaternions:

$$(a+eb)^{-1}(e[ix_1+jx_2+kx_3] + x_4)\ (a-eb) =$$

$$e[ix'_1+jx'_2+kx'_3] + x'_4 .$$

This representation is complete and exhaustive. It is seen that our limiting process $R \longrightarrow \infty$ causes degeneration of pseudorotations into euclidean translations.

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2. KRONSBEIN, J. 1946. Elliptic geometry, conformal maps, and orthogonal matrices. Duke Math. Jour. 13:505-519
3. STUDY, E. 1903. Geometrie der Dynamen. Leipzig.

PHYSICS

Chairman: DUANE ROLLER, Wabash College

C. Hire, Indiana University, was elected chairman for 1951.

ABSTRACTS

Beta spectrum of Rb^{86}*. E. BLEULER and R. M. STEFFEN, Purdue University.—Rb^{86} is reported to decay by emission of two β-ray groups.[1] Since an anisotropic β-γ-correlation has been found[2] the shape of the partial β-spectrum which is followed by the γ-ray should deviate from that for an allowed transition. Coincidences were measured between the β-particles focussed in a double-coil lens type spectrometer and the γ-rays detected with a scintillation counter. A source of 0.08 mg/cm^2 was used, prepared from a sample of Rb^{86} obtained from the Isotopes Division of the U. S. Atomic Energy Commission. The conventional Fermiplot shows no distinct deviation from a straight line above 0.27 Mev. The application of different correction factors will be discussed. The Fermi-plot of the total β-spectrum shows a definite curvature which is slightly overcompensated by the application of the correction factors for first and second forbidden transitions.

Isomerism of In^{110}*. J. W. BLUE and A. C. JOHNSON, Purdue University.—The (α, 2n)-reaction on silver leads to an activity of about 5 hours half-life assigned to In^{109}. A similar period is found for the product of an (α, 3n)-reaction[3] and has been assigned to In^{108} (from Ag^{107}), since In^{110} (from Ag^{109}) was known to decay with a half-life of 65 min. On the other hand, a period of 55 min. has been found for In^{108} produced by a (d, 2n)-reaction on Cd^{108} [4]. The discrepancy has been removed by showing that In^{110} has an isomer of 4.8±0.3 hours half-life. It was found by following the decay of the conversion electrons emitted from the well known level at 656 kev of Cd^{110}. A conversion line corresponding to a γ-ray of 119 kev follows approximately the same period and may be due to the isomeric transition.

Nuclear energy levels from proton groups in (α, p) reactions. M. LOREN BULLOCK, WILLIAM O. MCMINN, and MILO B. SAMPSON, Indiana University.—Thin targets of Be^9 and C^{12} have been bombarded with 23 Mev α-particles from the Indiana University cyclotron. The number

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* Supported by the ONR

[1] D. J. Zaffarano, B. D. Kern and A. C. G. Mitchell, Phys. Rev. 74, 682 (1948)

[2] D T. Stevenson and M. Deutsch, Bull. A.P.S. 25, No. 2, 9 (1950)

[3] S. N. Ghoshal, Phys. Rev. 73, 417 (1948)

[4] E. C. Mallary and M. L. Pool, Phys. Rev. 76, 1454 (1949)

of protons given off at 90° relative to the cyclotron beam has been measured for various proton energies. This was done by placing various aluminum absorber foils in front of a proportional counter biased so as to count only those particles that stop in the counter. From the proton groups thus found we have calculated the ground states and excited states of the product nuclei, B^{11} and N^{14}, respectively.

Radiations from Mo^{99} and Tc^{99m}. ROBERT CANADA and ALLAN C. G. MITCHELL, Indiana University.—The radiations from Mo^{99} (67 hrs.) and its metastable daughter Tc^{99m} (6 hrs.) have been measured in a magnetic lens spectrograph. The beta-ray spectrum consists of a group with an end-point energy of 1.23 Mev, one of 0.445 Mev, and possibly a third lower energy group. The relative intensities of the 1,23-Mev to 0.445-Mev groups are 4:1. Gamma rays have been found at 0.040, 0.140, and 0.181, 0.367, 0.741 and 0.780 Mev. The gamma rays at 0.040, 0.140 and 0.181 Mev are internally converted. The spectrum of Tc^{99} consists of one internally converted gamma ray at 0.140 Mev. A disintegration scheme is proposed.

The optical properties of semiconducting materials. H. Y. FAN and M. BECKER, Purdue University.—Silicon and germanium are found to have high transparency for infrared radiation beyond a sharp absorption edge. The absorption coefficient is determined by measurements of transmission through bulk samples. It increases towards long wave-lengths and is larger for samples of lower resistivity. The absorption, though small, is higher than predicted by either the usual or a more elaborate theory of absorption by free carriers. On the other hand measurements on neutron irradiated silicon show that free carriers do play an important role in the absorption. Measurements at low temperatures show that in certain cases localized energy states are important for the absorption. The position of the sharp absorption edge checks approximately with the known width of the energy gap and shifts with temperature. Theoretically calculated temperature dependance of the energy gap, which agrees with estimates based on electrical measurements, is in good agreement with the observed shift in silicon, but is too small to explain the shift in germanium. Reflectivity measurements by Lark-Horovitz and Meissner are also reported. Both materials have constant reflectivity over wide regions in the infrared, from which the index of refraction is calculated to be 3.5 and 4.0 for silicon and germanium respectively. With high transparency and constant large index of refraction these materials may find useful applications in infrared work, and the sharp rise of the absorption edge makes them good filters.

New approximation method for treatment of order-disorder transitions. HUBERT M. JAMES and LLOYD D. FOSDICK, Purdue University.—The order-disorder problem of the square Ising array in two dimensions has been discussed by an extension of Bethe's method. A 3x3 section of this array is considered, and account is taken of (a) the tendency of interaction with external atoms to induce short-range order, as well

as long-range order, in the outer sites of this section, and (b) the differing control of long-range order exerted by this interaction for non-equivalent sites in the outer shell. The theory thus involves three parameters instead of the one parameter of Bethe's theory. This more careful treatment of short-range order greatly improves the accuracy of the method, which in an elementary manner yields results comparable to those of Kramers and Wannier, and much superior to those of other approximation methods. The predicted Curie point is some 7% higher than the exact value. The short-range order is in good agreement with the exact results of Onsager for all temperatures, with maximum error around the Curie point. The theory predicts a specific heat varying like $(T\text{-}T_c)^{-1/2}$ as T approaches the Curie temperature T_c from below, whereas other approximation methods predict finite values; Onsager's exact result varies as — log $(T\text{-}T_c)$.

Fermi levels in semiconductors. GUY W. LEHMAN, Purdue University.—In nucleon irradiated semiconductors additional donator and acceptor states appear.[1] The Fermi level changes as a function of the total number N of defects introduced. When more donator levels than acceptor levels are introduced, P-type material changes to N-type during bombardment. For equal numbers of donators and acceptors (lattice vacancies and interstitials) produced, with activation energies of 0.15 ev. and 0.05 ev. respectively, the Fermi level in all cases approaches the limiting value 0.275 ev. above the middle of the forbidden gap as N increases: initially N-type material is converted to P-type material and initially P-type material shows decreasing resistance if the initial concentration of impurities is moderate as observed in Ge. A model corresponding to bombardment-induced transmutations[2] producing three acceptor impurities for each donator shows that N-type material is converted into P-type and P-type material shows decreasing resistance, again as observed in Ge after heat treatment to remove lattice imperfections.

1. LARK-HOROVITZ, K. et al, Deuteron Bombarded Semiconductors, Phys Rev. 73, 1256(A), 1948.

2. CLELAND, J. W., LARK-HOROVITZ, K., and PIGG, J. C., Transmutation-produced Germanium Semiconductors, Phys. Rev. 78, 814(L), 1950.

Observations on the Michelson Interferometer. RALPH A. LORING, University of Louisville.—If the dividing mirror of the Michelson Interferometer is not silvered two sets of fringes will be formed. These may be formed in different planes and so they may be separated if a telescope is used for observation. However, there are some circumstances under which both sets are desirable. Both sets may be observed simultaneously without confusion if a grid is placed at the collimating lens. Then one half of the field will contain one set of fringes and the other half will contain the other set.

Angular correlation of the gamma-rays emitted from the excited states of A^{38*}. R. M. STEFFEN, Purdue University.—The angular corre-

* Work supported by the ONR.

lation of the two γ-rays emitted in cascade from A^{38} after the β-decay of Cl^{38} has been measured using two anthracene scintillation counters and a coincidence circuit with a resolving time of 5.8×10^{-8} sec. The apparatus was checked by a careful measurement of the known correlations obtained from Ni^{60} and Pd^{106}. In the case of A^{38} the probability that the two γ-rays are emitted at an angle ζ is proporational to $f(\zeta) = 1 - (1/3) \cos^4 \zeta$. This correlation is characteristic for two quadrupole quanta and angular momenta 3, 2, 0 for the states involved. While the values of the spins are in agreement with the results obtained by the study of the β-decay of Cl^{38} a serious dfficulty arises in the assignment of parities. The relative intensities of the partial β-spectra suggest the same parity for the ground state and the first excited state, the opposite parity for the higher excited level. On the other hand, the quadrupole character if the two γ-rays and the small probability of the cross-over transition require the same parity for all three states.

A method of determining the dielectric constant of moist air at a frequency of 9500 megacycles. CLAYTON M. ZIEMAN, Wabash College.—The resonance frequency of a cavity changes when the medium filling the cavity is changed. If a cavity is first evacuated, then filled with moist air and the change in resonance frequency observed, the dielectric constant of the moist air can be calculated. Actually two cavities are used, one serving as a reference cavity. The shift in the resonance frequency is observed by having the resonance pulses, on the same time base, appear simultaneously on an oscillograph screen. This is done by electronic switching.

High energy radiations from V^{48}*. W. ZOBEL, Purdue University.—V^{48} decays by positron emission to a level of Ti^{48} of 2.31 Mev excitation energy, from which two γ-rays are emitted in cascade. Supplementary to a proposed investigation of the angular correlation of these γ-rays, a search was made for high energy positrons and a cross-over γ-ray employing the cloud chamber method of Morganstern and Wolf.[1] The V^{48} was produced by bombarding Ti^{48} with deuterons and separated chemically. A small number of high energy positrons is emitted, probably in a direct transition to the ground state of Ti^{48} with an intensity of $4 \times 10^{-4}\%$. The cross-over γ-ray was found in 4.6% of the decays. Tentative assignments of spin and parity to the different states will be given.

* Supported by the ONR

[1] K. H. Morganstern and K. P. W. Wolf, Phys. Rev. 76, 1261 (1949)

A Rapid Temperature Recording Method

G. E. McINTOSH and J. E. BROCK, Purdue University

At the outset the general problem of this research was that of determining the thermal diffusivities of a number of metals. Of the several available methods the one selected was the periodic unsteady-state procedure as applied to one-dimensional heat flow down a slender rod.

Experimentally this method (Fig. 1) involves taking continuous temperature-time data at two points on a metal rod, one end of which is subjected to some arbitrary periodic temperature wave or pulse. The length of the time period and the distance between the two temperature measuring points are additional factors that must be accurately determined. With this data the phase lag of the temperature wave between the two points can be calculated and from this the thermal diffusivity is computed.

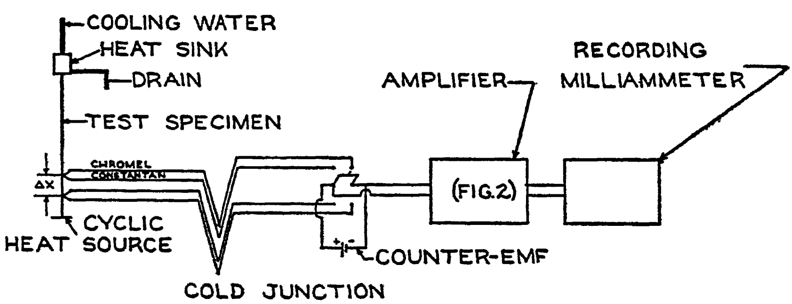

FIGURE 1
THERMAL DIFFUSIVITY TEST APPARATUS

With these considerations known it was immediately evident that at least two elements would be necessary for the measuring circuit; these components being a temperature-sensitive element and some kind of recording device. The thermocouple properties of low heat loss, quick response, durability, and low cost effectively dictated their use. In practice No. 36 chromel-constantan thermocouples were used. Selection of the recording device was considerably influenced by the availability of various types of meters. After investigating all the factors that were then known about the method to be employed, an Esterline-Angus Recording Milliammeter with 0-5 ma. scale was selected to do the recording.

Having determined the end points by selecting the thermal element and recording meter the next task, and actually the crux of the measur-

ing problem, was to join the two components in a manner capable of giving satisfactory results. For this purpose an amplifier was introduced to magnify the thermocouple signal so that its power might be great enough to actuate the recording milliameter. Because of the uncertainty of dc. amplifiers it was decided to "chop" the input signal and use a conventional 60 cycle amplifier. Following an appreciable developmental period the amplifier circuit shown in Figure 2 was built and found to be satisfactory.

The functioning of the thermocouple amplifier is as follows: The emf. from the thermocouple is led to the Brown Converter which is actuated from the 6.3 volt filament tap as shown in Figure 2. The "chopped" 60 cycle alternating signal is transferred to the 6SJ7 tube by the 1:15 shielded input transformer. After the two stages of R-C coupled amplification the current is boosted by the 6L6 power tube and then rectified by the 6X5. This resultant dc. current is recorded by the recording milliammeter. (Values of the components are given in Table I.)

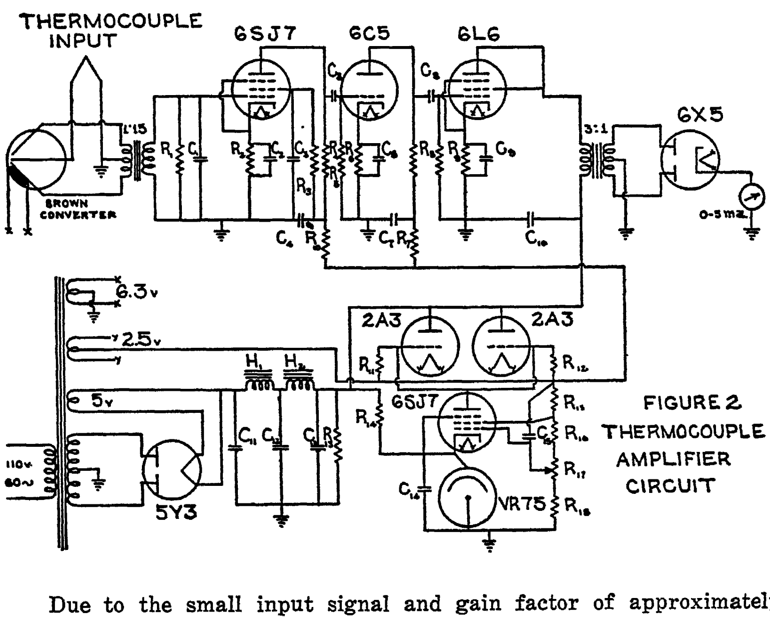

FIGURE 2. THERMOCOUPLE AMPLIFIER CIRCUIT

Due to the small input signal and gain factor of approximately 10^4 some difficulty was experienced in obtaining a stable output and low noise level. The output was successfully stabilized by installing a voltage regulator[1] in conjunction with the power supply. It should be noted that the voltage regulator feeds only the two amplifier stages because it was found that the 6L6 caused the output voltage to be lower than was desired. The noise level was reduced considerably by heavily

[1] Radio Amateurs Handbook, 25th ed., 1948, p. 244

TABLE I. List of component parts for the amplifier.

R_1, R_4, R_8, R_{14}	100 K	ohms
R_2	600	ohms
R_3, R_{11}, R_{12}	500 K	ohms
R_5	250 K	ohms
R_6	4000	ohms
R_7, R_{10}, R_{18}	5000	ohms
R_9	250	ohms
R_{13}	15 K	ohms
R_{15}, R_{17}	10 K	ohms
R_{10}	24 K	ohms
C_1	0.02	microfarad
C_2, C_6, C_9	10.	microfarad
C_3, C_5, C_8, C_{14}, C_{15}	.1	microfarad
C_4, C_7, C_{10}	20.	microfarad
C_{11}, C_{12}	8.	microfarad
C_{13}	40.	microfarad
H_1, H_2	10.0	henrys

shielding the "chopper" with a steel box and by installing a well-shielded input transformer.

Using this amplifier an input of 0.3 mv. gives full-scale output of 5 ma. on the milliammeter which corresponds to approximately 7.5° F. for chromel-constantan thermocouples. The output characteristic of the amplifier is linear up to 4.5 ma. Due to the limited range of the amplifier-recorder combination some source of bucking emf. is supplied at the input so that the unit actually operates over a 7.5° F. temperature range above any predetermined datum. In practice a potentiometer is used to provide the bucking emf. Work on the project is continuing and a new amplifier is being built which should show an appreciable improvement over the present model.

In a number of instances good data has been obtained using the arrangement as shown in Figure 1. It is expected that the experimental procedure will be much simplified and the results more reliable when two amplifiers are available for recording the temperature curves for both thermocouples simultaneously instead of averaging groups of readings for each couple, as is necessary with only one unit.

Methods for Controlling a Constant Temperature Bath

P. E. McNALL, J. R. WOOLF, and J. E. BROCK, Purdue University

In the course of some studies on the thermal conductivity of liquids, it was necessary to construct constant temperature baths. Although the basic principles of these control devices are not new, it was thought that a description of our arrangements might be of interest to others.

Consider a thermo-sensitive element made of a long copper coil (44 feet of ½ inch tubing) filled with a low viscosity oil (Stanolex Transformer Oil). The thermal expansion of the oil provides the principle for control of the bath. Oil was chosen for the temperature sensitive element because of its large thermal coefficient of volumetric expansion. A long length of copper tubing was used in order to present as great an area as possible for heat flow between the bath and sensitive element. The copper coil terminated in a mercury filled reservoir so that the change in volume of oil was registered by a change

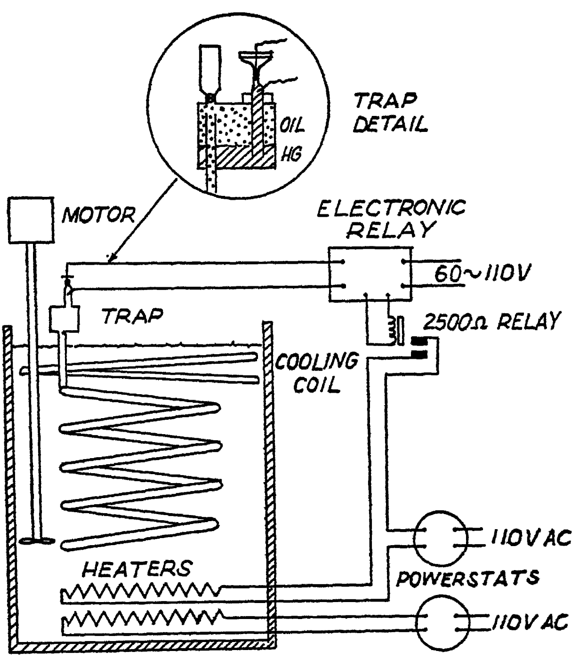

FIG. 1 SCHEMATIC DIAGRAM OF BATH AND CONTROL

in the mercury level in a vertical capillary tube. A trap was necessary to prevent seepage of the oil past the mercury, since mercury does not wet glass walls. Traps made either of glass or steel worked equally well. An ordinary darning needle served as a contact point, so that as the mercury would rise in the capillary tube it would contact the needle, closing the electric circuit to actuate the relay and shut off the heating current as shown in Figure 1. The surface of the mercury in the capillary should be protected from the atmosphere. Methyl salicylate was used for this purpose as recommended by Eastern Industries, Inc. (2). The bath consisted of about 20 gallons of the same light transformer oil that was used in the regulator coil.

If any considerable arcing occurs at the needle to mercury contact it will cause contamination of the mercury surface and reduce the sensitivity. It was necessary, therefore, to devise a relay that could be actuated by a very small current while switching very large amounts of power from the 110 volt a.c. lines. Such a circuit (3) is shown in Figure 2. When mercury is not in contact with the needle, the grid of the 6F6 tube has zero bias through the one meg ohm resistor and the

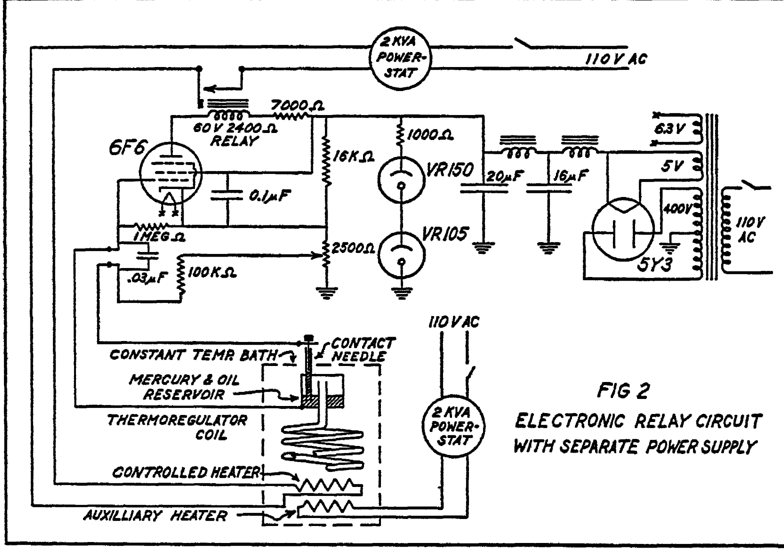

FIG 2
ELECTRONIC RELAY CIRCUIT WITH SEPARATE POWER SUPPLY

relay closes. As the temperature increases the mercury contacts the needle and the grid circuit is completed through the 2500 ohm variable bias resistor set to the correct value for "cut off," the tube blocks, and the relay opens and cuts off the heating current. The small condenser across the thermoswitch reduces relay chatter due to vibrations. This relay is quite stable and remains in operation for long periods without re-adjustment. Since the contact points are in the grid circuit of an electron tube circuit, the current at "make and break" is of the order

of a few microamperes. This regulator circuit controlled the temperature of the bath to approximately ±0.02°F over the range 77°F to 145°F. The period of the heating cycle varied from 2-8 minutes and the best control was obtained with the longer periods.

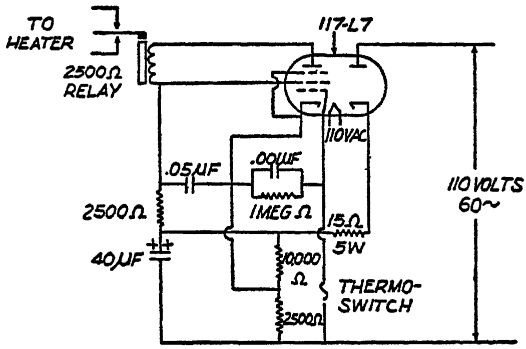

FIG. 3 SINGLE TUBE ELECTRONIC RELAY

A much simpler control circuit is shown in Figure 3. The rectified power for operation of the circuit is supplied from the diode section of the 117L7 tube and the pentode section of the tube serves the same purpose as the 6F6 tube in Figure 1. As before, the thermoswitch is in the grid circuit and the relay in the plate circuit of a power tube and the operation is the same as previously described. This circuit is unique in that a single tube, operating wholly from the 110 volt a.c. line, gives as good control as the more complex arrangement of Figure 1.

In checking the sensitivity of the relay control circuits described in the preceding paragraphs, one method used employed a Western Electric, type 14-B, thermistor (1) in conjunction with a 5-dial wheatstone bridge and a Leeds/Northrup, type 2500-a, galvanometer. A 2 cm. deflection of the light beam (1 meter from scale to galvanometer) on the scale corresponded to 0.04°F temperature change. This observation suggested the use of a photo cell relay circuit, activated by the galvanometer light beam in conjunction with a thermistor, as the temperature control element for a constant temperature bath. Since the thermistor has a negative thermal coefficient of resistivity of about 2% per degree Fahrenheit over the range of temperatures contemplated in the experiment, it makes a very sensitive control device. Another advantage of the thermistor as a control device is its very small thermal capacity.

The direct coupled amplifier circuit for the thermistor temperature control is shown in Figure 4, and was designed and constructed by the Campus Electronics Service at Purdue University. When light strikes the photocell, the grid of the first section of 6SN7 tube becomes less negative and the conduction of the section increases. At the same time

the conductance of the second section of the 6SN7 tube decreases and the relay opens the heater circuit. When the light moves off the photocell the effect is reversed and heater power is restored. The schematic bridge circuit arrangement for the thermistor and galvanometer is shown in Figure 4-a. In order to make the system the most sensitive the light beam was directed on the edge of a mirror as shown in Figure 4-b. The light source was a 21 c.p. lamp mounted in a Leeds/Northrup lamp and scale reading device from which the scale had been removed.

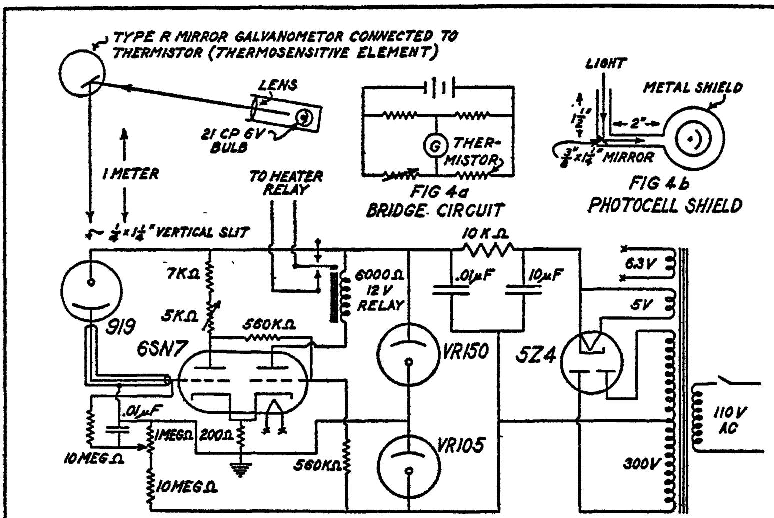

FIG 4 PHOTOCELL RELAY CIRCUIT

The optical system in Figure 4-b consisted of a metal cover for the photocell with a ¼" x 1¼" vertical slit for illumination. A ¼" x 1¼" x 2" tube shielded the slit, with a ⅜" x 1¼" mirror set at 45° in the end of the tube. Another tube at right angles to the first completed the arrangement. The inside of the shield was covered with carbon black.

Tests employing this photocell relay control showed that the light deviated only about ±1 mm. from the zero point for "off" and "on" control, which is equivalent to a control of about ±0.002°F. The system is stable and operates with a minimum of attention.

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2. Eastern Industries, Inc., 1950. New Haven, Conn.
3. SWIETOSLAWSKI, W. 1946. Microcalorimetry. Reinhold Publishing Company, pp. 1-186.

PSYCHOLOGY

Chairman: ROBERT BRUCE, Wabash College

G. A. Zirkle, Hanover College, was elected chairman for 1951.

ABSTRACTS

Hoarding in the white rat under isolation and group conditions. V. H. DENENBERG, Purdue University.—Sixteen male CF Wistar rats, reared under group conditions and ranging in age from 43 to 57 days at the start of the experiment, were the subjects. The rats were randomly divided into four groups and allowed to hoard under four different sequences of isolation and group conditions (I-I-G-G; G-G-I-I; I-G-I-G; and G-I-G-I) for a period of twenty consecutive days. The rats were fed a deprivation diet of two Purina Dog Chow pellets per day during the experimental trials.

The purpose of the experiment was to investigate two opposing hypotheses of hoarding—Morgan's "deficit hypothesis" which states that there is competition between eating and hoarding, and Bindra's hypothesis which maintains that the same factors which influence eating also influence hoarding—and also to determine whether there was differential hoarding as a function of the different sequences of isolation and group conditions.

An analysis of variance technique was used to analyze the data. It was found that the rats hoarded significantly more under isolation conditions than group conditions. It is suggested that this result was due to social facilitation of eating under group conditions. It was concluded that when deprivation is used as the motivating variable, there is competition between eating and hoarding and the results are interpreted as lending support to' Morgan's hypothesis.

It was also found that there was a significant increase in the number of pellets hoarded under the second group condition as compared to the first one. It is suggested that this increase was due to "emotional adjustment" of the rats.

Generalization of a muscle action potential response to tonal duration. JOHN B. FINK, Indiana University.—*Problem:* To investigate the stimulus generalization gradient, when the stimulus is tone, varied in the dimension of duration, and the dependent variable is a muscle action potential of the extensor digitorum muscle of the preferred arm.

Subjects: Twenty-five students with one year or less of psychology courses.

Procedure: 'Ss were presented with three series of tones. In

Series I, a control series designed to determine the extent to which size of action potential is a function of tonal duration before training, three presentations each of five durations were given randomly; i.e. fifteen presentations in all. The durations were 2.0, 2.25, 2.5, 3.0 and 4.0 seconds. Series II was a training series in which ten presentations of the 2-second duration were given. In Series I and II, Ss were instructed to press key at every presentation. In Series III, the experimental series, ten presentations each of both the 2-second tone and one of the five test durations was given to each S. In this series, Ss were instructed to press key only when tones like those in Series II were presented.

Results: (1) Analysis of variance for action potential response measures in Series I indicated that for durations between two and four seconds muscle action potential did not seem to be a function of tonal duration before training. (2) Analysis of variance for response measures in Series III indicated that for durations between two and four seconds, action potential was a declining function of difference between test duration and training duration. (3) By treating the action potential responses at the various stimulus durations as normal distributions, and by locating a "critical pressing value" in the first of these, it was possible to predict, very closely, the per cent of key pressings for the other durations. This suggests that there are responses which form a stimulus generalization gradient, these being only occasionally (when they are large enough) manifest as overt responses.

Implications for psychotherapy as derived from learning theory. LEE GUREL, Purdue University.—The aim of this paper is roughly twofold: (1) to point up the often cited need for research into the nature of therapy and therapeutic techniques; to propose as a medium for this study those learning and behavior theories both known to general psychology and those in need of further elucidation and formulation; to cite the values of this medium and give examples of its applicability; and (2) within the framework, tentatively outlined, to point out some of the assumptions involved in our therapeutic practice and theory; to examine some of the implications of these assumptions; to suggest further hypotheses and how they might be clarified; and finally, to examine some of the current points of disagreement among therapists of divergent orientations.

Investigations of the behavior of *Paramecium aurelia*: I. Modification of behavior after training with reinforcement. B. GELBER, Indiana University.—It was the purpose of this study to investigate learning in a protozoan by the use of a more or less classical design which had yielded adequate results with metazoa. Two experiments are reported. For each experiment, 12 cultures of about 128 homozygous *Paramecium aurelia* each were divided into 2 groups of 6 cultures each. In each case, an experimental culture was matched by a control culture of heredity and environment as close to identical as possible. In Experiment I, 6 cultures were given 40 training trials with one third periodic

reinforcement under hunger motivation, while matching cultures in each instance were given no training. Training trials consisted in lowering a platinum wire into the culture for 15 seconds, with 25 seconds between trials. Reinforcement consisted in wiping a very small amount of food or bacterial suspension on the wire before it was lowered. Experiment II was the same as Experiment I, except that no reinforcement was given during training.

Tests for learning were made by counting the number of animals which adhered to the sterile wire after it had remained in the culture for three minutes. Curves for mean responses during training of both reinforced and non-reinforced groups are shown. Final test scores for all groups are evaluated by a t test. The following conclusions are drawn:

1. Significant differences in final scores existed only in the reinforcement group, which gave a value of t significance at almost the .005 level when compared with their own controls and a value of t significant at better than the .01 level when compared with the non-reinforced group.

2. Training without reinforcement did not have any detectable effect.

3. The behavior of *P. aurelia* is modified after training with reinforcement of this sort.

Some implications of the class concept for clinical psychology. ROBERT S. ORT, Wabash College.—The training of clinical psychologists for the past several years has been chiefly in the "practical" or applied areas of psychology. This type of training has resulted in the slighting of at least two other areas of psychology. These being; social psychology and learning theory.

Psychologists and sociologists have been developing various systems for the differentiation of the American Culture into its sub-cultures. The two men that have the clearest systems to date are Warner and Centers. Centers' approach is more of an economic breakdown, whereas Warner's system is suggestive of various learning environments.

Warner sees the American Culture as consisting of six general divisions, which he has termed class. These classes are the upper-upper class, lower-upper class, upper-middle class, lower-middle class, upper-lower class, and the lower-lower class. The classes then fall into three general forms of learning environments. These learning environments often permit individuals to learn overt behavior that appears to be similar even though the individuals have learned the behavior in different learning environments. Thus a middle-class child may display aggressive behavior that is similar to the behavior that is displayed by a lower-class child. The aggressive behavior, however, is indicative of a relatively "healthy" adjustment when displayed by a lower-class individual, whereas, this same behavior is indicative of maladjustment when displayed by a middle-class child.

The same problem holds true in the attempted diagnosis of social

behavior and intelligence. From this we must conclude that clinical psychologists must have some awareness of the social structure in order to accurately diagnose behavior. The same conclusion may be reached in terms of therapy. The aggressive lower-class individual must be taught social structure since his problem does not result from lack of contact with reality, but rather from not understanding "enough" of reality. On the other hand, the aggressive middle-class individual must be supplied cues to the causes of his behavior which is not reality oriented.

The usefulness of the integration of the class concept and clinical psychology has been grossly oversimplified in this paper, but as a step towards such an integration the author feels that the oversimplification is justified.

Resistance to extinction of a lever pressing response in white rats as a function of number of reinforcement. L. B. WYCKOFF, Indiana University.—Six groups of white rats, on 22 hours water deprivation, were given different numbers (0, 2, 4, 6, 12 and 100) of water reinforcements for lever pressing. The animals were subjected to experimental extinction immediately following the reinforced trials. The mean numbers of responses to extinction for the six groups were 32.6, 42.1, 56.0, 77.7, 84.4, 127.6, respectively.

The relationship between resistance to extinction and number of reinforcements can be described fairly adequately by the simple growth function:

$$R = 96.6\ (1 - e^{-.075n}) + 31$$

in which R represents the responses to extinction and n the number of reinforcements. A comparison of this curve with those obtained by Williams and Perin indicates that the form of the relationship between resistance to extinction and number of reinforcements is relatively independent of the kind of reinforcement used (food vs. water) and other experimental conditions which differed in these experiments. Both the data of this experiment and those of Williams' study exhibit small but possibly systematic deviations from a simple growth function which merit further investigation.

ZOOLOGY

Chairman: SEARS CROWELL, Indiana University

C. J. Goodnight, Purdue University, was elected chairman for 1951.

ABSTRACTS

Additions to our knowledge of *Obelia* and *Campanularia*. SEARS CROWELL, Indiana University.—Our texts rarely tell more about *Obelia* than was known in 1872 (Allman). Both *Obelia* and the related *Campanularia* have been studied often since then, especially by experimental morphologists. Much has been added of significance and interest. Attention is called to the contributions of Lund, Huxley, De-Beer, Hammett, Hauschka and especially to those of Berrill. His analysis of the development of hydranths, gonangia, medusae, and stolons offers an explanation of the differences among those components of a colony and also of the differences among species.

The following observations, made in collaboration with Malcolm Rusk, apply to colonies of *Campanularia flexuosa*. Although the growth of a hydranth is more rapid at 21°C than at 17°C, the number of new hydranths produced is much greater at the lower temperature. The development of young gonangia is usually accompanied by (compensatory?) regression of the nearest hydranth. By amputation, colonies were obtained with either reduced stolon systems or reduced stems and hydranths. It was expected that these might show compensatory growth to give typical colony proportions. To the contrary, new components were produced from each locus of growth without reference to the altered composition of the colony.

The polyp stage of *Craspedacusta*. SEARS CROWELL, Indiana University.—Specimens are obtained by setting slides in a quarry where medusae occur, or by careful search among the algal growth. (No original observations.) —Demonstration.

Heterotopic transplantation of neural crest and melanogenesis in salamanders. L. E. DELANNEY, Wabash College.—It is characteristic of most salamander larvae to be devoid of pigment cells on the ventral surface during early development. That the ventral migration of prospective melanophores from the neural crest is actually stopped at the ventral tips of the somites has been demonstrated in the Californian salamander, *Triturus torosus*. Other salamanders do not appear to have any specifically located barrier to migration but nevertheless prospective melanophores fail to descend to the belly region. Only at metamorphosis does there appear any great population of pigment cells

in this region. Transplantation of neural crest cells was made to the belly to demonstrate the influence of this ventral environment on melanogenesis. Under these conditions melanophores develop as normally as in the orthotopic position. The condition is transient, however, and the melanophores soon "de-grade" and appear extremely small, punctate and contracted. The fate of these cells in larval and metamorphosed stages is discussed.

Stability of a stream fish population. II. SHELBY D. GERKING, Indiana University.—Knowledge of the movement of stream fishes is essential to understanding the characteristics of stream fish populations. A quarter-mile section of Richland Creek, Greene County, Indiana was the site of a three-year investigation designed to show the extent of movement characteristic of several species native to the stream. The stream has a maximum width of 60 feet, a maximum depth of 3 feet and flows over bed rock. Fish were marked in 1948 and 1949 by clipping off one or a combination of the pectoral and pelvic fins. The fish were caught with the electric fish shocker. Of the fish marked in the early summer of 1948 and recaptured in the late summer of the same year, 75 per cent of them were caught within 100-200 feet from where they had been marked. A search for the fish marked in 1948 was again made in mid-summer of 1949. In this instance 80 per cent of the fish were found "at home" although a year had elapsed between the time of marking and their recapture. Additional fish were marked in 1949 and a search was made for them in 1950. Again 75 per cent were found in the same place in the stream where they had been marked.

Longear sunfish was the dominant centrarchid species and in the three-year period it was found in the same location where it had been marked 82 per cent of the time. Similar values for other species during the three-year period are: rock bass, 87 per cent; green sunfish 75 per cent; smallmouth bass 58 per cent; spotted bass 79 per cent; three species of suckers 56 per cent.

It should be emphasized that fish found in "foreign territory" had strayed only a relatively short distance because only a quarter-mile section of the stream was worked in all three years. The "homes" of at least three species have very limited boundaries, in the neighborhood of 100-200 feet. This indicates that the Richland Creek population is relatively stable from one year to the next even though violent changes in water level, breeding habits of the fish, seasonal changes in temperature, and many other factors might all be expected to influence their movement.

The development of the pronephros in the leopard frog ***(Rana pipiens).*** O. C. JAFFEE, Indiana University.—The first sign of pronephric development in the frog is noted in the 2.5mm embryo where a thickening of the mesoderm occurs, just posterior to the gill anlagen. This thickening develops rapidly into a solid rod shaped mass of cells, extending posteriorly about one third of the embryo, lateral to the somites. At the anterior of this mass an opening develops. By the

next stage (muscular response stage) definite division of the somatopleure and splanchnopleure has occurred, and tubular formation is noted. At this stage the duct is seen leading posteriorly and ending blindly. The pronephric body rapidly develops into a compact, tubular body. In the next (heart beat) stage three nephrostomes are noted and the duct has joined the cloaca, so that the pronephros would seem to be anatomically complete before hatching.

At hatching considerable development of the pronephros has taken place and this proceeds rapidly so that at the stage where the operculum has been completed, the pronephros has increased a great deal in size and vascularization. The mesonephros is noted in the 15mm. tadpole; the mesonephros becomes the recipient of the pronephric duct, and its duct, in turn, leads to the cloaca. But degeneration of the pronephros does not seem to be as rapid as hitherto reported. Well developed pronephri, as well as mesonephri are noted in the 17mm., 23mm., and 37 mm. stages.

Alkaline glycerophosphatase in the developing thyroid, thymus, pituitary, and parathyroid of the albino rat. RICHARD J. MCALPINE, Indiana University.—The technique of Gomori was used with slight modification in this study. The differentiative phase of the thyroid cells is characterized by a marked increase in phosphatase content. This increase occurs during the differentiation of cells from the ultimobranchial bodies as well as from the median thyroid diverticulum. The decrease in phosphatase consequent upon differentiation corresponds in time with follicle formation. A moderate increase in phosphatase occurs during the differentiative phase of the thymus. In this case the disappearance of phosphatase is correlated with the appearance of large numbers of thymocytes. A marked increase in phosphatase, followed by a decrease during late fetal life, occurs in the developing pituitary. The parathyroid exhibits no increase in phosphatase activity.

The clear-cut association of phosphatase with the differentiative phases of the thyroid and pituitary suggests that the enzyme is associated with the actual chemical mechanism of differentiation. The fact that the parathyroid does not exhibit these changes serves to indicate the existence of a multiplicity of chemical mechanisms of terminal differentiation. In addition, these findings yield data pertinent to the problem of thyroid formation from ultimobronchial tissue, and to the problem of the relationship between the epithelial and lymphocytic components of the thymus.

.Segmental vascular patterns and behavior in *Nereis virens* and *Nereis limbata*. PAUL A. NICOLL, Indiana University.—The absence in both species studied, of any specialized part that functions as the heart, focuses interest on the segmental vascular details that are essentially repeated in each of the numerous segments. The modifications present in the head and tail portions are related to body structure and make no specific contribution to vascular function.

The slides shown indicate semi-diagramatically the structural com-

ponents of the vascular system in a typical segment of *N. virens* and *N. limbata.* The outstanding modification is the presence of dead-ending capillary-like vessels that apparently form the chief, if not only, terminal supplying vessels to muscle and other internal structures. Each segment also possesses capillary nets on the surface just beneath the chitinous layer, which are thorough-fare channels and probably serve only as respiratory exchange sites. The intestine also is served by a complex, continuous capillary net. The structural organization of the dead-ending capillary-like vessels in the two forms differ in that in *N. virens* they arise as branches from larger vessels that eventually continue on and break up into the superficial capillary nets; while in *N. limbata* the closed vessels arise mainly from a special branch of the ventral vessel.

Blood flow is achieved by means of peristallic waves of contraction that pass over all of the vessels except the large mid-ventral vessel and the true capillary plexuses. Direction of flow, which is usually from ventral to dorsal through the parapodia, is determined by different frequencies of the peristallic waves in the major vessels.

These contraction waves are due to a peristallic spread of activity in slightly branched, essentially circularly placed, smooth muscle cells. It does not appear to be either induced, controlled nor regulated by nervous means since no nerves could be demonstrated in the vicinity of any vessel by vital staining techniques.

A method of collecting assorted protozoa for class study. THEODORE T. ODELL and SEARS CROWELL, Indiana University.—Slides in racks are placed 4 to 6 feet deep in a suitable body of water. After about 10 days these acquire representative species of most of the fresh water orders of Sarcodina and Ciliata. Students in our invertebrate class have given a better response in studying these slides than they did when we furnished the usual pure or mixed cultures of protozoa. (Demonstration).

Observations on *Acetodextra amiuri*, a digenetic trematode from the ovary of catfish. KENNETH W. PERKINS, Purdue University.—*Acetodextra amiuri* is unique among digenetic trematodes in that it occurs as an adult in the gonads of the definitive host. Almost every female catfish taken from the Wabash River has proved to be infected; over 2000 worms were recovered from the ovaries of one fish. Evidently the parasite destroys the eggs in the ovary since young worms have been observed within the egg and the intestine of older ones is filled with yolk. Whereas other digenetic trematodes lay eggs within the host, *A. amiuri* apparently does not. Instead, the eggs accumulate in the uterus which becomes greatly distended. When worms are removed from the host and placed in tap water, either directly or after remaining in saline for several days, the body bends ventrally and strong muscular contraction causes the uterus to rupture through the dorsal body wall and burst, projecting eggs several millimeters. This behavior suggests that the life cycle is continued by passage of mature

worms into the water when the host spawns. Investigations of the life cycle of this species are in progress. It is especially favorable for observing stages of gametogenesis and embryology. Pseudoreduction observed in both spermatocytes and oöcytes indicates that the diploid number of chromosomes is twelve.

The effects of various species of bacteria on the growth of *Trichomonas vaginalis in vitro*. ENOS G. PRAY, Purdue University.—The growth of *T. vaginalis* with single species of bacteria in the medium of Sprince and Kupferberg (1947) has been compared with that in bacteria-free controls. Observations included determinations of pH and oxidation-reduction potentials. Controls showed a growth curve reaching a peak of almost 2,000,000 flagellates/ml. on the third day after inoculation. Thereafter, the number decreased gradually until the eighth day and then rapidly, flagellates disappearing from the cultures on about the tenth day. The results obtained when grown with single species of bacteria varied with the bacterium employed. With *Escherichia coli, Aerobacter aerogenes,* and *Pseudomonas aeruginosa,* growth of the flagellate was retarded during the first 24 hours and living ones disappeared from the medium within 48 hours. With *Bacillus subtilis, Staphlococcus albus, Staphlococcus aureus* and *Pseudomonas fluorescens,* flagellates persisted about as long as in control cultures but never reached as high a reproductive rate. With *Alcaligenes faecalis,* the growth curve of *T. vaginalis* attained a peak above and sooner than that in controls, but the flagellates disappeared from the medium more rapidly. Filtrates of cultures of all the bacteria used gave results which were similar to those obtained when the bacterial cells were present but were less pronounced. Present evidence indicates that the effects of bacteria are primarily nutritional in nature, and when unfavorable, are not due to specific antagonistic substances or changes in the oxidation-reduction potential or pH of the medium.

Experimental thyroid tumors derived from ultimobranchial tissue in the rat.[1] JOHN H. VAN DYKE, Indiana University School of Medicine. —The origin, circumstances and mode of development of thyroid neoplasms in mammals has been regarded as an enigma. Recent investigations indicate, however, that thyroid *metaplasia,* which can be induced, invariably, in both lobes of the thyroid gland of the rat by an actual or latent state of vitamin A deficiency, is a manifestation of ultimobranchial tissue, an accessory epithelial component of the mammalian thyroid gland, and can be an associated phenomenon in the genesis of thyroid tumors. "Thyroid-like" vesicles, indistinguishable from typical thyroid tissue at birth, but formed during embryonic development from a "plastic" (and therefore labile) ultimobranchial body, transform in postnatal rat thyroids into more or less formidable cysts (frequently multiple) lined by stratified squamous epithelium after variable periods of vitamin A deficiency (depending on age of the animal).

Simultaneous feeding of a goitrogen (Allylthiourea—2mg. daily)

and a carcinogen (2-Acetylaminorfluorene—2 mg. daily) in vitamin A deficient diet, utilizing different age groups, has resulted in the production of *demonstrable* thyroid neoplasms of distinct ultimobranchial cyst origin in a large percentage of the animals. These tumors, at present, are single, of a relatively solid (epithelioid) type, potentially malignant, although possessing a variable blood supply, and arise from the basal or germinative layers of such cyst walls. They occupy the position in which the fetal ultimobranchial body would be expected to lie.

The evidence indicates that metaplasia is (or can be) a fundamental preneoplastic manifestation during thyroid ontogenesis. Under the stimulatory conditions of our experiments the evidence points toward ultimobranchial tissue as the source of certain "true" neoplasms in the mammalian thyroid gland. (Demonstration)

Systematic notes on the tapeworm family Acoleidae. J. DAN WEBSTER, Hanover College.—The genera *Progynotaenia* and *Proterogynotaenia* are rediagnosed, and new species are describd from North America. *Shipleyia inermis* and *Gyrocoelia milligani* are recorded from new hosts. The family *Progynotaeniidae* is regarded as inseparable from *Acoleidae*.

Injuries by Venomous Animals in Indiana

SHERMAN A. MINTON, JR.,[1] Indiana University Medical Center

Although injuries inflicted by venomous animals are by no means a major problem in the midwest, the interest and concern shown by the general public requires that the zoologists be able to recognize these animals and have some knowledge of their habits.

According to data obtained by the Department of Public Health Statistics of the Indiana State Board of Health, twenty-one deaths due to poisoning by venomous animals were reported from Indiana during the years 1930 to 1949 inclusive. This figure is almost certainly too low, however, for such deaths occurring in the occupations of agriculture or forestry have, since 1934, been merged into the general category of agricultural accidents and are not listed separately. The species of animal involved is not given in the statistical listings and is known only in those cases which have been investigated by the writer or others. At least 3 of the deaths in the series are ascribed to insect stings, one to spider bite, and 4 to snake bite. The age of the victim is not given in 12 cases; under 10 years in 5 casés, between the ages of 25 and 64 in 3 cases, and over 64 in one case. Males outnumber females about three to one. There has been a marked decline in the number of fatalities in recent years; 16 of the cases occurring prior to 1940. It is interesting to compare the Indiana data with that compiled by Swartzwelder (6) for Louisiana where there were 51 deaths during the years 1930 to 1945 inclusive.

Of the known venomous animals, only the spiders and snakes are represented in the midwest by potentially dangerous species. Stinging insects present a special case; since serious or fatal injuries result from hypersensitivity, multiple stings, or infection. The scorpions, an important group in tropical and subtropical regions, are absent except for an occasional accidently introduced individual. The larger of our native centipedes, particularly the common orange or grey *Scolopendra* sp., will bite if restrained but produce only local pain and swelling.

The dangerous nature of the black widow spider, *Latrodectus mactans*, is well known. The dangerous form of this spider, the adult female, is ordinarily easy to recognize. No other medium-sized spider in our geographic area has such a shiny, black, polished appearance. The bright red hour-glass spot on the underside of the abdomen is a good field mark (Figure 1). In younger females it is often combined with a row of red spots along the dorsal midline. All red marks may be absent in rare cases. I saw one large female *Latrodectus* that was chocolate brown with cream yellow bars on the sides of the abdomen, a

[1] I am indebted to Mr. and Mrs. John H. Daily, Mr. H. E. Riddell, and members of the Illustration Department of the Indiana University Medical Center for their aid in the preparation of the photographs.

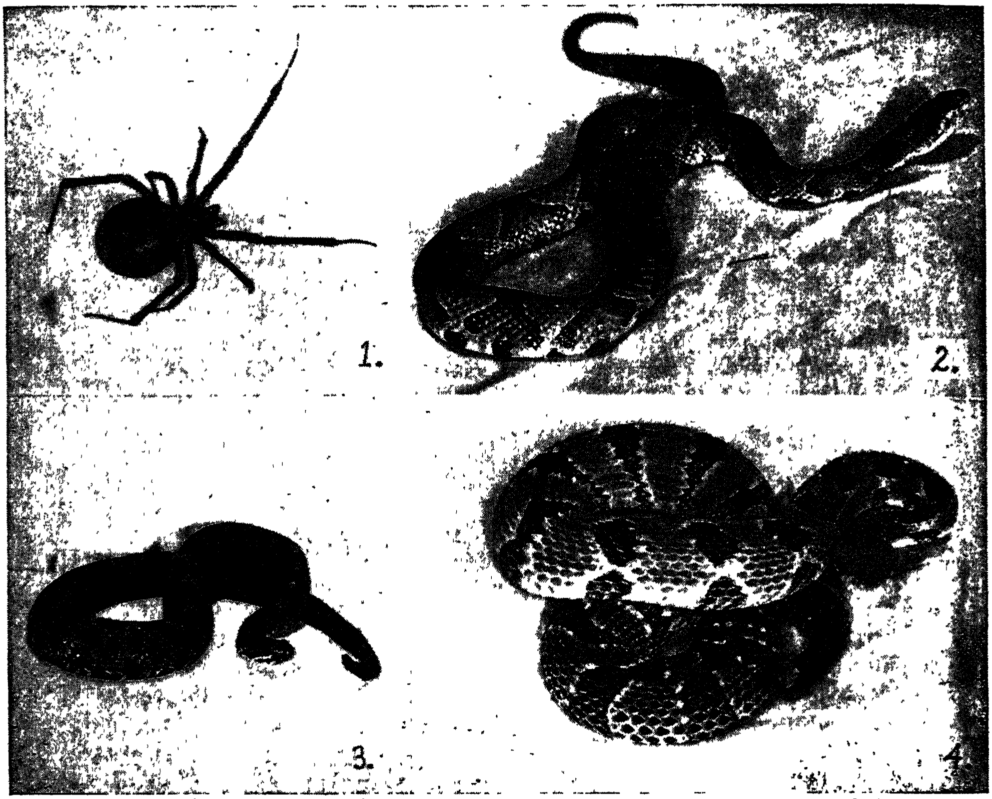

FIG. 1. Black widow spider *Latrodectus mactans*. Adult female collected in Ohio Co., Indiana.

FIG. 2. Copperhead *Agkistrodon contortrix mokeson*. Adult female collected near Kurtz, Jackson Co., Indiana.

FIG. 3. Massasauga *Sistrurus c. catenatus*. Adult male collected in Starke Co., Indiana.

FIG 4. Timber rattlesnake *Crotalus h. horridus*. Adult female collected in Jackson Twp., Brown Co., Indiana.

midline row of orange spots, and an orange hour-glass. This seems to represent a case of abnormal persistence of the normal juvenile pattern and color.

The black widow is known from all parts of Indiana but appears to be considerably more plentiful in the southern half of the state. Most specimens I have encountered have been concealed beneath stones, boards, scraps of metal, cardboard, and other rubbish. Rather open, dry, warm situations are preferred; deep, moist woods and swampy areas are usually avoided. Reasonably clean, well-kept houses do not afford a favorable habitat for this spider; however, specimens may be introduced in baskets of vegetables, firewood, etc. Several alleged

black widows found in houses have been identified as *Phidippus audax*, a small blackish jumping spider with an orange dorsal spot. Barns, garages, tool sheds, and other outbuildings are better refuges for *Latrodectus* and may be quite heavily infested in some cases. The web of the black widow is never neat and geometrical and rarely located in the open. The construction of the web is very irregular; the strands coarse and unusually strong.

Most published data on cases of black widow poisoning have been obtained in the southern and southwestern United States and in tropical regions. This may be the result of greater interest in the problem, more accurate case finding, or greater abundance of the spiders. It is also possible that there may be geographic variation in potency and quantity of venom and with respect to the readiness with which the spiders attack man. In most published accounts, bites occurred when the spiders became entangled in clothing or when webs, particularly webs containing egg sacs, were accidentally touched. Several authors stress a high incidence of accidents among persons using outdoor privies. It has been my experience that the black widow almost invariably attempts to escape when disturbed in the field. An attack reaction may sometimes be elicited by touching the web of captive spiders particularly during the period of egg-guarding.

Bogen (1) reported 17 deaths in a series of 380 cases of black widow poisoning from 18 states. Stahnke (5) reports 7 fatal cases of spider bite in Arizona in a 20-year period. Three were definitely ascribed to the black widow. Data for Indiana and the surrounding territory are meagre. Cases of spider bite do occur; however, the offending arachnid is rarely identified. About four years ago, a fatal case occurred in Ripley County, the victim being an 81 year old woman. The spider was said to have been "probably a tarantula", but this would seem rather unlikely. I know of at least two non-fatal cases ascribed to the black widow and two cases ascribed to the wolf spider (*Lycosa* sp.). The latter were not accompanied by symptoms of generalized toxemia; although there was considerable local pain and swelling. It may be mentioned in passing, that severe cramping abdominal pain with marked muscular rigidity is perhaps the most pronounced symptom of arachnidism due to the black widow and may lead to confusion with such conditions as acute appendicitis or ruptured peptic ulcer especially since the bite may not be particularly painful and produce little local swelling or discoloration. Greer (3) considers burning sensations in the soles of the feet a highly significant symptom which may permit diagnosis when the history of a bite cannot be obtained.

Control of these spiders in the vicinity of dwellings requires the cleaning up of such trash as may shelter the animals with destruction of adults and eggs as found. Insecticides including DDT are not particularly effective. A spray of 15% unslaked lime in kerosene is recommended by Gowanloch (2) but must come in direct contact with the spiders. Creosote is repellent to *Latrodectus* and may be used for the treatment of privies.

The incision and suction treatment recommended as a first aid

measure in snake-bite seems to be of little value in arachnidism. In fact, no first aid treatment except possibly the local application of cold appears useful. The intravenous injection of 10% calcium gluconate, which is readily available and stable indefinitely, often gives dramatic relief from the symptoms. Commercially prepared antivenin or the serum of patients who have recovered from bites has been used with good results but is rarely available.

The species of poisonous snakes known to inhabit Indiana are the timber rattlesnake, *Crotalus h. horridus*, the massasauga or swamp rattlesnake, *Sistrurus c. catenatus*, and the copperhead, *Agkistrodon contortrix mokeson.* None of these snakes pose much of a recognition problem except the copperhead whose rather distinctive pattern and form (Fig. 2) may be learned by the observation of a few captive or freshly-preserved specimens and the very young massasauga with its tiny rattle and markings like a young fox snake or hog-nosed snake. Dead specimens of any of these snakes may, of course, be readily identified by the presence of fangs, loreal pits, elliptical pupils, and undivided sub-caudal plates. All of the numerous Indiana reports of water moccasins I have investigated have been based upon harmless species; however, the venomous moccasin is common in parts of southern Illinois and may occur in Posey and adjoining counties. Older writers sometimes include Indiana in the range of the coral snake on the basis of a specimen from Ripley County reported by Bigney in 1891. There have been no further reports from the state, although a specimen turned up recently in the suburbs of Cincinnati.

The massasauga (Fig. 3) originally inhabited wet prairies, peat bogs, and swamps throughout the northern half of Indiana. It has never been reported in the state south of Indianapolis. Its present-day distribution is very local and spotty. Drainage and agriculture have greatly reduced its numbers particularly in the Till Plains where it is virtually extinct. Copperheads occur throughout the southern part of the state and range northward in the west at least to the Turkey Run area. I have records for 20 counties. Dry, rocky, wooded ridges are the preferred habitat, and the species may be quite numerous locally. The timber rattlesnake (Fig. 4) has similar habitat preferences, and its original range in Indiana was probably much the same as that of the copperhead. It is now quite rare except in a few wild areas. Specimens are regularly taken in sections of Brown, Monroe, Morgan, and Martin Counties with a few reports from other places. The reforestation of considerable tracts in southern Indiana with restoration of much of the original biota may well cause both these reptiles to increase in number.

Information on 30 cases of snake bite in Indiana has been collected and is presented in Table I. The mortality rate in the series is probably too high; for it is the severe and complicated cases that are reported or remembered. The copperhead and the massasauga, which account for 25 of the cases reported, are probably unable to inflict a fatal bite upon an adult unless the picture is complicated by infection,

TABLE I. Snake-bites in Indiana 1930-1950

Patient & Locality	Site of Injury	Species of snake	Circumstances under which injury sustained	Treatment	Result
Boy 12 Clark Co.	finger	Copperhead	Attempting to capture snake	Incision & suction Permanganate	Uneventful recovery
Adult female Jefferson Co.	ankle	Large Copperhead	Stepped on snake while climbing hill	Incision & suction Antivenin	Recovery. Swelling of leg persisted several weeks
Infant Crawford or Perry Co.	face	Copperhead?	Child crawled under porch of house	Apparently none	Died "in a few minutes"
Adult male Clark Co.	hand	Copperhead	Attempting to capture snake	Incision & suction	Uneventful recovery
[1]Adult male St. Joseph Co.	finger	Massasauga 18"	Clearing obstruction from blades of mowing machine	Incison & suction	Uneventful recovery
[1]Boy 4 LaPorte Co.	finger	Large Massasauga	Unknown	Incisions Antivenin—3 doses	Death 7 days later from hemolytic anemia
Boy 16 Floyd Co.	finger	Copperhead 23"	Touched captive snake in sack	Incisions Antivenin	Recovery: some residual stiffness of finger
Adult male Monroe Co.	right forefinger	Copperhead	Taking up rug in old house	Incision Antivenin	Uneventful recovery
Girl about 6 Morgan Co.	leg	Timber Rattlesnake	Stepped on snake in high grass	Unknown	Died
Girl 7 Brown Co.	right ankle	Copperhead	Unknown	Incisions, Antivenin $MgSO_4$	Minimal symptoms. Recovery
Boy 3 Brown Co.	left foot	Copperhead	Unknown. Apparently bitten at same time as preceding patient	Same as above	Moderate symptoms. Recovery

TABLE I. Snake-bites in Indiana 1930-1950—Continued

Patient & Locality	Site of Injury	Species of snake	Circumstances under which injury sustained	Treatment	Result
Boy 2 Floyd Co.	foot	Copperhead 20″	Playing near woodpile	Incisions Antivenin	Moderately severe symptoms. Recovery
Adult male Crawford Co.	unknown	"Water Moccasin"2	Working on construction gang near river	Said to have drunk a large quantity of whiskey	Died
Boy 10 Floyd Co.	finger	Copperhead	Touched a snake while climbing among rocks	Antivenin only	Recovery
Adult male Marion Co.	finger	Copperhead 11″	Measuring captive snake	Incision & suction MgSO4 soaks	Uneventful recovery
Adult male Brown Co.	thumb	Timber Rattlesnake	Showing captive snake to friends	Incisions, antivenin	Severe local reaction. Recovery
Adult male Parke Co.	hand	Copperhead	Picked up snake—mistaken for harmless species	Unknown	Uneventful recovery
Girl 4 Fulton Co.	foot 2 bites	Massasauga 12″	Playing in yard	Incisions Antivenin	Severe symptoms. Recovery
Adult male Marion Co.	hand	Diamond-back Rattlesnake	Handling snake in sideshow	Incision & suction Antivenin	Severe symptoms. Recovery
Adult male Brown Co.	finger	Copperhead	Transferring captive snakes from cage to bag	Antivenin	Severe serum reaction. Recovery
Boy 14 Miami Co.	left leg	Massasauga 24″	Unknown	Antivenin, Incisions, Tetanus antitoxin	Uneventful recovery
Adult male LaGrange or Noble Co.	finger	Young Massasauga	Picked up snake—mistaken for harmless species	Unknown	Recovery

Boy 10 Bartholomew Co.	right foot	Copperhead?	Moving a large rock in woods	Incisions. Antivenin, Tetanus & gas-gangrene antitoxin	Minimal symptoms. Recovery
Adult female Porter Co.	left hand	Massasauga	Working in yard	Antivenin	Recovery
Adult male Orange Co.	finger	Copperhead	Reached into empty feed sack	Unknown	Recovery
Girl 7 Brown Co.	hand	Copperhead	Playing in abandoned woodshed	Unknown	Recovery after rather prolonged illness (poss.secondary infection)
Adult male Dubois Co.	hand	Copperhead	Reached into corn crib	Antivenin	Recovery
Boy 3 Parke Co.	right hand	Copperhead?	Unknown	Incisions & packs. Tetanus antitoxin	Moderate symptoms with good recovery
Adult male Vigo Co.	left forefinger	Florida pigmy Rattlesnake 20"	Working with captive snake in laboratory	Incisions, MgSO4 and Borax packs	Minimal symptoms Recovery
Adult male Vigo Co.	hand	Small Massasauga	Working with captive snake in laboratory	Incisions MgSO4 packs	Recovery

[1] Cases previously reported by Lyons and Bishop (1935).
[2] So reported to me. Probably copperhead or timber rattlesnake.

psychogenic shock, marked debility, or the results of injudicious treatment. Some cases are so mild a doctor may not be consulted. The bite of a large timber rattlesnake is much more serious, but the rarity and rather mild disposition of this snake make accidents uncommon.

In this series of cases, almost one third involved individuals attempting to capture venomous snakes or persons engaged in handling these animals. Two additional cases were the result of picking up a venomous snake that had been mistaken for a harmless species. Poisonous snakes should be captured and maintained in captivity only by responsible individuals aware of the danger involved and willing to take all due precautions. The handling of snakes purely as a display of bravado is deplorable.

Eleven cases, three of them fatal, occurred in children of ten years or less. In addition to the child's greater susceptibility to the venom, small stature and a greater tendency to assume the quadrupedal posture predispose to bites high upon the limbs or upon the body or face.

Many of the snake-bites in this series were sustained close to home. Snakes become abundant about dwellings only if there is a plentiful supply of food—usually small rodents—and suitable shelter. A loosely-constructed stone wall or foundation, a pile of old lumber, or a tumble-down shed if located in a favorable spot will attract snakes in surprising numbers. Thorough search of a large log pile in Floyd County revealed six copperheads and six other species of reptiles and amphibians including a black kingsnake that had eaten a seventh copperhead. The cleaning up of such habitats will greatly reduce the incidence of snakes about dwellings. It is safer to remove boards and other litter during the winter or early spring when snakes are inactive; however, a campaign in mid-summer may dispose of gravid females before young are born. Occasionally country residents report a brief but rather striking invasion of their premises by snakes usually during the late summer. There is good evidence that timber rattlesnakes and copperheads as well as certain harmless species follow rather well-defined routes between summer ranges and hibernating areas. The snakes will continue to use these routes despite the presence of human habitation. On the Morgan-Monroe State Forest there is a rattlesnake crossing where one or more of these reptiles is killed each August in nearly the same spot on the black-top road.

Observations on the copperhead in southern Indiana indicate that the snakes hibernate on wooded, rocky hillsides. They emerge from hibernation late in April but remain close to the hibernating area for about a month before gradual dispersal to summer ranges. During the summer, the reptiles hide by day and forage actively by night. Late in August, the snakes return to the hibernating area rather promptly and remain there basking on mild days until the middle of October. It is probable that both local species of rattlesnake follow a similar schedule. Nearly all snake-bites in this series excluding those by captive reptiles were sustained during the period of summer activity which also coincides with the peak of human outdoor activity. Although

information is available in only a few cases, the majority of bites seem to occur between the hours of six and nine in the evening. It is fortunate that, during the summer, the snakes are feeding frequently thus reducing the possibility of receiving a maximum dose of venom.

Since the treatment of snake bite is unpleasant and not without danger in itself, it is important to determine first that the suspected bite was really caused by a venomous snake and second that an appreciable amount of venom was injected. Much unnecessary alarm and undeservedly vigorous treatment has been occasioned by bites of harmless snakes or even wounds by inanimate objects. There are also a few well-authenticated cases where actual bites by venomous snakes have not been accompanied by any indications of poisoning. Insofar as our species are concerned, an effective bite is promptly followed by pain, marked local swelling, and discoloration.

In the treatment of snake bite, opinion is divided as to the relative merits of surgical treatment—ligature, incision, and suction—and the use of antivenin. Although further clinical observations and experimental work are required, it appears that antivenin may be used to supplement surgical treatment but should never supplant it. If a tourniquet is used as a first aid measure, it must be loosened at intervals. Gangrene has resulted from improper use of ligatures. Potassium permanganate has no place in the treatment of snake bit. Weak solutions are inferior to epsom salts as a wet dressing while strong solution can cause great damage. The definitive treatment of snake bite, particularly the injection of antivenin, should be entrusted to a physician except in the most dire emergency.

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Some Effects of 2-Thiouracil on *Rana clamitans* Larvae[1]

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Investigations concerning the thyroid gland in the larval forms of representative anurans have usually involved an analysis of experimentally produced hypofunction or hyperfunction with respect to retarded or accelerated metamorphosis. It has been shown that the thyroid glands of tadpoles begin to concentrate iodine very early in development (1). However, there is little evidence to indicate that the hormone is actually being secreted or, that if it is released in appreciable quantities, whether it bears any relation to premetamorphic ontogeny.

The purpose of these experiments was to investigate the effects of 2-thiouracil on non-metamorphosing *Rana clamitans* larvae to determine the time of the beginning of normal thyroid secretion and its role in larval ontogeny.

Materials and Methods

Thirty to 32 eggs obtained by induced ovulation (4) were placed in each of eight 8" finger bowls filled with one liter of tap water and aerated continuously from the beginning of the experiments. The animals in two of these bowls were used for controls while each of the three levels of thiouracil employed was tested on the animals in two separate bowls of those remaining. The water was changed every other day and the thiouracil was added to the clean water to make concentrations of 0.015, 0.030, and 0.045%. The animals were permitted to feed on one gram of Pablum placed in the bowl 6-8 hours before changing the water. One of the control series and one of the two series tested with each level of thiouracil were weighed on the seventh day and every week on the same day throughout the course of the experiments. The other four series were not weighed as regularly. Body weights were determined by removing the animals one at a time to damp filter paper and transferring them by means of dry filter paper to the arm of a torsion balance and weighing to the nearest milligram. Animals studied histologically were fixed in Bouins' fluid, dehydrated in alcohol, embedded in paraffin, and 8 micron sections were stained with Harris' Haematoxylin and Eosin.

Results and Discussion

Effects on body weight—Days 1-21. There was no significant difference in the body weights in the groups of animals when the experiments began. Thiouracil treatment was begun on the ninth day and there was no effect detectable on the 14th; however, on the 21st day the average

[1] Contribution No. 458 from the Department of Zoology, Indiana University.

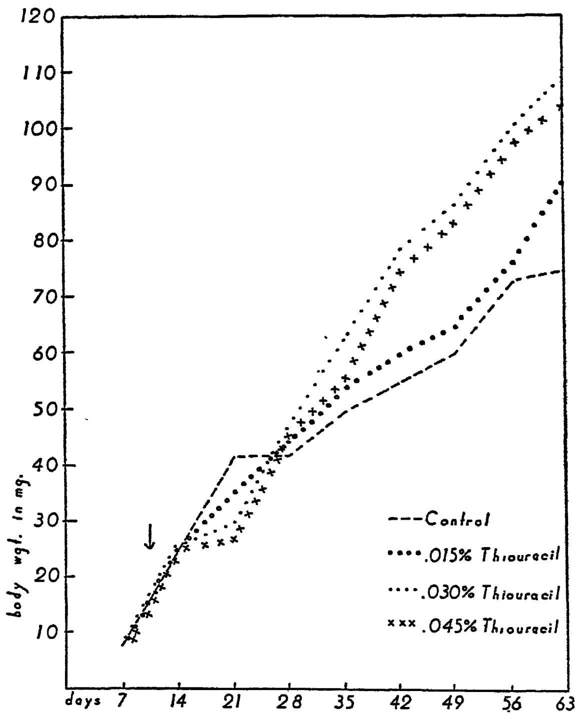

FIG. 1. Body weights of *R. clamitans* larvae weighed weekly from first to ninth week. Each point represents the average of weights of not less than 25 larvae. Arrow indicates beginning of thiouracil treatment.

body weights of all the thiouracil treated groups are significantly lower than those of the controls (Fig. 1). A sample of 10 of each of the series receiving the same treatments but not weighed on the 7th and 14th day, shows that this effect of decreased growth is not due to handling the animals. It is thought that this effect is due to an increase in the endogenous circulating thyroid hormone. Gordon et al (2) reported a notable decrease on the colloid content of thyroid glands of 20-30 mm. tadpoles after 10 days of treatment with 0.033% thiourea, and it has been noted previously in this laboratory that additional thyroid substance causes a decrease in the average body weight of treated larvae.

Effect on body weight—Days 28-63. The average body weights of the thiouracil treated animals, with the exception of the 0.015% group, are significantly greater than that of the control from the 35th day to the termination of the experiment. Growth is unquestionably greater in the animals treated with 0.030 and 0.045% thiouracil (Table I).

This conclusion is supported by the fact that the average body weights of samples of the series receiving the same treatments but

TABLE I. Average body weights of *Rana clamitans* larvae

Days		7	14	21	28	35	42	49	56	63
Treatment										
Control	(15)	7	24	42	42	48	53	58	71	72
				(3.21)	(0.88)	(1.33)	(1.66)	(0.85)	(0.47)	(1.48)
0.015%	(16)	7	24	35**	44	53	60	62	74	90
				(6.60)	(1.74)	(3.57)	(4.40)	(4.43)	(3.70)	(3.68)
0.030%	(17)	7	25	29**	46	62**	75**	85**	100**	109**
				(3.27)	(0.94)	(3.53)	(3.34)	(3.87)	(3.54)	(5.60)
0.045%	(18)	7	24	32**	45	56**	71**	81**	97**	104**
Control	(19)			43	48	55	54	49	55	
								(3.48)	(3.25)	
0.015%	(20)			33	46	54	61	59**	72**	
								(6.88)	(8.16)	
0.030%	(21)			33	51	64	75	76**	88**	
								(8.80)	(7.12)	
0.045%	(22)			31	54	63	76	81**	96**	
				Means of samples of ten weights						

**Differences are significant at the 1% level. Numbers in ( ) above the mean body weights of the experimental groups represent the "t" value of the difference from the controls.

not weighed in their entirety each week, showed the same significant difference for the treated larvae.

The possibility that crowding the animals is responsible for the effects observed is unlikely since the differences in the number of animals per group is slight and there are actually somewhat more in the treated groups toward the end of the experiments.

Thus the effect of 2-thiouracil with respect to growth varies with time. It would seem that thiouracil first results in a curtailment of hormone production and a release of stored colloid by the thyroid under the influence of the pituitary. This results in a temporary depression of growth. Then when the stored hormone is used up and no more can be produced by the thyroid the level of circulating hormone drops below normal and growth becomes excessive in the thiouracil treated larvae.

Effect on the gonads. The bodies of five animals from each of the four series sacrificed at 56 days were sectioned and the length of both the right and left gonads was determined by counting the number of sections in which a portion of the definitive gland appeared (Table II). The average gonad lengths of all the thiouracil treated groups are significantly greater than that of the control. With one exception, the right gonad is shorter than the left in the animals examined, but the same significant difference in length is noted for the right gonad alone in larvae treated with 0.030% and 0.045% thiouracil and in all the thiouracil treated groups for the left gonad alone. The length of both the right and left gonad show a high degree of positive correlation with

TABLE II. Measured and calculated mean gonad lengths of *Rana clamitans* larvae as determined from histological preparations. Animals were fixed on the 56th day after fertilization, after 47 days of treatment with the concentrations of thiouracil indicated.

Treatment	Average body weight in mg.	Average number of gonad sections				Calculated average gonad lengths	"t" for mean lengths
		Left	"t"	Right	"t"		
Control (19)	55.4	96		83		0.707 mm.	.
0.015% Thiouracil	68.6**	128**	8.83	79	1.16	0.787 mm.**	3.70
0.030% Thiouracil	73.0**	123**	3.39	99**	5.81	0.868 mm.**	9.87
0.045% Thiouracil	92.6**	139**	3.60	102**	3.71	0.931 mm.**	3.62

** Significant at 1% level.

the body weight giving correlation values of 0.5 and 0.8 respectively, both values being significant at the 1% level when tested by the "t" test (5).

Effect on the thyroid gland. The effect of thiouracil after 21 days of treatment is thought to be related to its effect on the thyroid gland resulting in a curtailment of hormone production. This is supported by an analysis of the thyroid glands made after 47 days of treatment. Gordon et al (2) noted a marked regression to an atrophic state at the end of two months of treatment with 0.033% thiourea on *R. pipiens* larvae. Stages in this regression are reflected by the glands at the various levels of thiouracil employed in these experiments. At the 0.015% level the glands are larger than the controls and the follicles contain greater amounts of colloid. The picture is about the same with some follicles showing signs of collapse at the 0.030% level. The glands of the animals treated with 0.045% thiouracil show few distinct follicles containing colloid and in some sections organization is almost completely lacking. Thus the effect of thiouracil on the thyroid gland seems to be roughly proportional to the dosage level which in turn seems directly related to the differences in the body weight and gonad lengths.

Effect on differentiation. Differentiation in general does not seem to have been affected by the thiouracil treatments. Presumably the developmental changes attributed to the thyroid are due to a higher level of secretion coupled with other changes in the physiology of the larvae at the time of metamorphosis. In these experiments the hypothyroid larvae are apparently simply larger while their organization and complexity is comparable to the control.

In speculating on the cause of these effects on body weights and gonads, some change in the pituitary function as a direct or indirect result of thiouracil treatment may offer a temporary working hypothesis.

Hoskins (3) noted hyperplasia of the hypophysis in thyroidectomized tadpoles and if such a phenomenon might be taken as an indication of increased secretion of growth and gonadotrophic factors, the results obtained would be clarified considerably. Further work on the role of the pituitary in these phenomena is already in progress.

Thus it might be concluded that the thyroid is actively secreting by the 35th day, if not before, as shown by the changes in the body weight. Further it would seem that this secretion is necessary either directly, or indirectly through its effect on other reactions, for maintenance of normal growth.

Summary

Effects on the body weights, gonad lengths, and histological appearance of the thyroid glands have been noted following treatment of *R. clamitans* larvae with 2-thiouracil. The relation of these effects to the beginning of normal secretion by the thyroid and its function in ontogeny have been discussed relative to the action of thiouracil.

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An Unusual Aggregation of the Milliped *Zinaria butleri* (McNeill)[1]

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The appearance of large aggregations of organisms is always an interesting phenomenon to an ecologist. Some groups of animals are prone to aggregate quite regularly, either as a recurring daily phenomenon or as a seasonal one, and others appear in large numbers with a rather regular periodicity, as in the case of the well-known cycles among rodents. There are, however, fewer references in the literature to large aggregations of millipeds. Cloudsley-Thompson (1) of Cambridge University cites 21 recorded instances of mass migrations of millipeds in North America, 14 of which were in West Virginia. We can find only one record of aggregating millipeds in Indiana, a report by A. V. Mauck (2). During August of 1898 a swarm of millipeds, *Fontaria virginiensis* (Drury) appeared in the fields and woods south of the Indiana University Biological Station at Vawter Park on the south shore of Lake Wawasee. The swarm was very conspicuous with every square foot of roadway containing one or more individuals. The migration was noticed during the early hours of several days, moving in a northerly direction towards the lake a little over 100 feet away. Mauck reports that all traces of the swarm vanished in a few days. The specimens were all adults and all of about the same size.

On August 31, 1950 an unusually large concentration of the milliped *Zinaria butleri* (McNeill) was observed by the junior author on the stone bridge over McCormick's Creek in McCormick's Creek State Park near Spencer, Indiana. An estimated 6,000 of the one and one half inch millipeds were heaped together at the ends of the bridge railings and had spread in a serried layer over several square yards of the abutment's vertical surfaces. This estimate is possibly too conservative since it was obtained by allotting an arbitrary one square inch of closely covered surface to each milliped, while in some areas they were piled one upon the other to a depth of four or five. The greater part of the bridge was either bare of millipeds or was scattered with slowly moving individuals. The organisms in the denser masses were completely quiescent, but became active when disturbed by light prodding or stroking. The stimulated animals crawled over their fellows and often fell to the ground singly or in intertwined groups. The dislodged individuals crawled about aimlessly on the ground below the abutments,

[1] The writers are indebted to Dr. A. R. Bechtel of Wabash College for collecting specimens of the milliped on August 31 and to Dr. Nelle B. Causey of the University of Arkansas for the identification of the milliped and for bibliographic assistance.

making no apparent effort to regain their former position. No predators were seen to be availing themselves of the helpless throng; a probable factor was the decided odor of prussic acid emitted by the mass.

Very few millipeds were found in the area surrounding the bridge. It was not possible to determine whence they had come or the cause for the aggregation at that point.

On October 22 the senior author visited the bridge on which the aggregation had been observed. In the leaves and under stones near the abutments at the n.w. end of the bridge, living adults were found in numbers greater than one would normally expect to find in such a situation. There were also many dead specimens. The ground on the side of the abutment away from the road, sloping down toward the creek, was pitted with small holes 1-1.5 cm. deep and .75-1 cm. in diameter. In some places there was one hole every 3 or 4 cm. and in others somewhat fewer. The holes were most abundant close to the bridge. It seemed fairly evident that these holes had been made by the millipeds and since millipeds are reported to dig holes in which to deposit their eggs, it may be that this was the purpose of the holes. On the other hand, the holes may have been made as a sheltered niche since some of the living individuals collected were curled up in them. No evidence of eggs or young was found. Perhaps the eggs had hatched and the young had moved to other places.

Mr. Tom Overmire, the park naturalist, was consulted on October 22 and he reported that the millipeds had been very abundant in the area at the end of the bridge ever since late in June of this year. In his activities in the park he had occasion to pass the spot in question quite frequently and apparently the millipeds were there in large numbers during most of the summer.

When the initial observations were made on August 31 it was thought that this was a temporary phenomenon which had occurred a relatively short time prior to the observations. Mr. Overmire's evidence places a different complexion on the problem.

Most of the published reports of similar phenomena deal with migrations in which the organisms appear suddenly and are as suddenly gone. In this instance the millipeds remained in force in a relatively small area over a period of several months, and four months after they were first observed they were still moderately abundant.

Morse in 1903(3) suggested three possible causes of migration and aggregation of millipeds. He referred to the rather regular appearance of large numbers of millipeds, *Fontaria indiana* Bollman, at Cedar Point, Sandusky, Ohio. In this case it was attributed to a mating reaction as the aggregation occurred immediately prior to and during oviposition. Other cases have been attributed to overpopulation. Finally, Morse suggested that millipeds might move from low damp areas used in oviposition to higher regions where they could over-winter under logs and leaves.

Cloudsley-Thompson (1) quotes Sinclair (4) on the phenomenon of

sudden increase in numbers of various species of millipeds and their short duration. Sinclair suggests that there is a delicate correlation between the factors which hold an even balance of the population and a very slight disturbance may let loose a flood of fertility. Perhaps something of this nature is the explanation of the tremendous local increase in this species. This year may have been a particularly favorable one and the large number of individuals came together for breeding purposes. The evidence of the numerous holes in the ground points to this as a possibility. Any analysis of a set of environmental conditions which could account for the phenomenon would have to be on a long-range basis and could not be made to explain this isolated instance. The fact that millipeds take two years to mature makes such an analysis even more difficult.

A continued study of the location next year is planned, with the purpose of possibly finding evidences of many young individuals. Such a finding would support the suggestion that breeding was the major sudden increases in numbers of various species of millipeds and their factor in the aggregation.

The milliped involved in this study was described by James McNeill in 1888 from Bloomington, Indiana, as *Polydesmus butleri*. In 1939, R. V. Chamberlin set up the genus *Zinaria* for this and several related species.

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Metajapyx subterraneus (Packard) in Indiana (Aptera; Japygidae)

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The members of the Insectan order Aptera are relatively rare in collections but are probably fairly common in most temperate regions. Numerous species have been described from the eastern United States, mostly from soil. Nevertheless, the writer was surprised to find the large *Metajapyx subterraneus* (Packard) in a number of places in southern Indiana since it does not seem to have been recorded from the state. The insect reaches a length of nearly an inch, is almost wholly creamy white in color, and blind. It is found under rocks, usually imbedded in the soil, and apparently spends its entire life in such situations. One reason for its apparent rarity may be that it closely resembles a large staphylinid beetle larvae and as such has probably been passed over many times by collectors. The japygids can readily be distinguished by the presence of the peculiar pincers.

The species was first taken abundantly in the canyon below the falls at McCormick's Creek State Park, Owen County, Indiana, in late March 1950, by Mr. Richard A. Hamilton and the writer. Later it was found by others in similar situations in the canyon of Stoute's Creek, just north of Bloomington, Monroe County, and near Bedford in Lawrence County. It probably occurs rather widely over Indiana, but may show some correlation with the old glacial boundary.

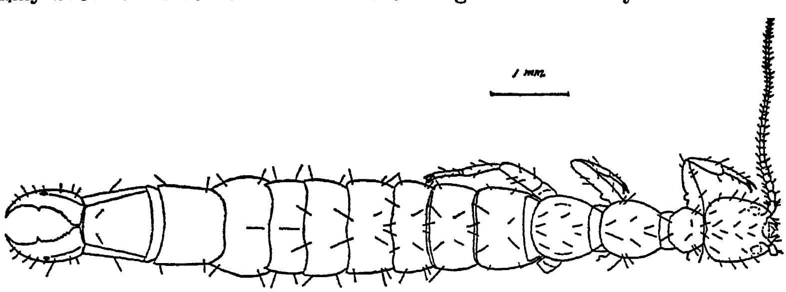

FIG. 1. Dorsal view of *Metajapyx subterraneus* (Packard).

The accompanying figure (Fig. 1) was drawn to scale from a specimen taken at McCormick's Creek State Park, March 28, 1950. It was kept alive for some time along with several others.

There is little agreement as to the order of insects to which the Japygidae belong. The older placement was with the Thysanura, but more recently they have been referred to Diplura, Dicellura, or Aptera. Essig (1947) argues that although the original Linnaean order Aptera has been reduced by the removal of many groups obviously misplaced

in it the order cannot be completely abandoned but must be retained for the Campodeidae, Japygidae, and Projapygidae.

The references (1, 2, 3, 4, 5) will aid in determination of specimens if other forms should come to hand.

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JUNIOR ACADEMIES

Sci-Math Club, Attica High School, Attica, Ind.
Up-N-Atom Science Club of Crawfordsville High, S. Green, Crawfordsville, Ind.
Future Scientists of America, Tolleston School, Gary, Ind.

INDIANA JUNIOR ACADEMY OF SCIENCE

Officers for 1950:

President: TOM MOON, Central Junior Academy, Central High School, South Bend.

Vice-President: SUE SHAFFNER, Chemistry Club, Shortridge High School, Indianapolis.

Secretary: MARILYN BECKETT, Biology Club, New Castle High School, New Castle.

Members of the Council: DARL F. WOOD, Mishawaka, (1947-1951); EVELYN WAGONER, Elkhart, (1948-1952); MAX FORSYTH, Indianapolis, (1949-1953); HAROLD STEWART, Bloomington, (1950-1954); ARTHUR L. SMITH, South Bend, (1951-1955).

PROGRAM OF THE EIGHTEENTH ANNUAL MEETING

November 4, 1950

Assembly Room, The Auditorium
Hanover College, Hanover, Indiana

9:00-10:00 a.m. Exhibits. Physics Laboratory, Physics Building

10:00 a.m. Morning Session, Assembly Room, Auditorium.

General session, Tom Moon, presiding.

Greetings, Dr. Grant T. Wickwire, Department of Geology, Hanover College.

Reading of minutes of the 1949 meeting, Marilyn Beckett, Secretary.

1. "Mendelian Laws and the Domestic Fowl," (illustrated), Harry Krueckeberg, Nature Study Club, Arsenal Technical High School, Indianapolis.

2. "The Entomologist and His Work," June Graves, National Scientific Honor Society, Bloomington High School, Bloomington.

3. Demonstration—"Analysis of a War Nickel With Emphasis on Electro-Deposition of Copper," William Arbaugh, (assisted by Miss Mona Jane Wilson), Science Club, Shortridge High School, Indianapolis.

4. "Reaction Rates of Trypsin," Wilfred Buchanan, Biology Club, Lew Wallace High School, Gary.

5. "Hydroponics," Joan Freeman, Science Club, Mishawaka High School, Mishawaka.

6. Demonstration—"Plastics," William Cook, Ralph Daveline, Roman Busick, Noel Kindt, Chemistry Club, Central Junior Academy, Central High School, South Bend.

7. "Medical Mycology Studies," Watson M. Laetsch, Science Club, Thomas Carr Howe High School, Indianapolis.

8. "Construction of Electrical Demonstration Units," Charlie Ellis, Science Club, University High School, Bloomington.

1:15 p.m. Afternoon session, Assembly Room, Auditorium.
Business session

9. "Preliminary Report of a Bird Breeding Population Study," Kelly Wise, Biology Club, New Castle High School, New Castle.

10. Demonstration—"Photography," Judith Shepherd, Jim LaFollette, Jim Pirtle, Bevra Boyll, Camera Club, Sullivan High School, Sullivan.

11. "Bacteria Studies of Vanilla and Chocolate Ice Cream," David Eads, Richard Theobold, Science Club, Thomas Carr Howe High School, Indianapolis.

12. "Taxidermy," Robert Petty, Science Club, Thomas Carr Howe High School, Indianapolis.

13. "Food Habits of Indiana Small Fish," Russell Noyes, Science Club, University High School, Bloomington.

14. "Brief Report on the Progress of the Junior Academy," Howard H. Michaud, State Sponsor, Junior Academy of Science, Purdue University.

15. "Toys and Science," Science Club, Centennial School, Lafayette.

16. Motion Picture—"The Fight Against Cancer," The Indiana Cancer Society, Indianapolis.

MINUTES

The eighteenth annual meeting of the Indiana Junior Academy of Science was held Saturday, November 4, 1950, in the assembly room of the Auditorium, Hanover College, Hanover, Indiana.

The exhibit room opened at 9:00 a.m., in the physics laboratory of the science building. Various scientific projects and demonstrations were displayed.

The general session was called to order by president, Tom Moon, Central Junior Academy, Central High School, South Bend. He next introduced the vice-president, Sue Shaffner, Chemistry Club, Shortridge High School, Indianapolis, and the secretary, Marilyn Beckett, Biology Club, New Castle High School, New Castle.

The minutes of the 1949 meeting were read by the secretary. Dr. Grant T. Wickwire, Department of Geology, Hanover College, welcomed the members of the Junior Academy and spoke of the relation of science to human living. He emphasized that "the soil of freedom is the only soil in which science thrives."

Harry Krueckeberg, Nature Study Club, Arsenal Technical High School, Indianapolis, opened the morning program with an illustrated talk on the "Mendelian Laws and the Domestic Fowl." He explained

the heredity in a chicken and the heredity of tallness and shortness in peas.

June Graves, National Scientific Honor Society, Bloomington High School, Bloomington, followed with a talk on "The Entomologist and His Work." She discussed the value of insect collecting as a hobby and explained the materials required and the methods used to obtain best results.

"The Analysis of a War Nickel with Emphasis on Electro-Deposition of Copper," was the topic presented by William Arbaugh, Shortridge High School's Chemistry Club, Indianapolis. He pointed out that the war nickel actually contained no nickel, but was composed of copper and other metals.

The possibilities of the use of trypsin in combatting tuberculosis and other lung diseases were discussed by Wilfred Buchanan, Biology Club, Lew Wallace High School, Gary, in a talk entitled, "Reaction Rates of Trypsin." He explained how future studies may benefit mankind.

"Hydroponics," was the topic discussed by Joan Freeman, Science Club, Mishawaka High School, Mishawaka. Two methods of growing plants with the use of water and chemicals were mentioned.

Next, William Cook, Ralph Daveline, Roman Busick, and Noel Kindt, Chemistry Club, Junior Academy, Central High School, South Bend, explained various processes used in making plastics.

Watson Laetsch, Science Club, Thomas Carr Howe High School, Indianapolis, explained his "Medical Mycology Studies." He discussed the processes of contamination and the methods used in making slides for the purpose of identification.

The morning program was concluded with a talk by Charlie Ellis, Science Club, University High School, Bloomington, on the "Construction of Electrical Demonstration Units." He used diagrams to show several electrical circuits and explained that these helped in the understanding of the actual circuits.

Many of the Junior Academy members attended the luncheon at which Mr. Marvin Amos spoke on the Soda-Bowl, the recreational center of the college.

The afternoon session was called to order at 1:15 p.m. The following students were elected as officers of the Junior Academy for 1951: David Thomas, Junior Academy, Elkhart High School, Elkhart, president; Judith Shepherd, Camera Club, Sullivan High School, Sullivan, vice-president; Marilyn Swift, Sciemus Club, Valparaiso High School, Valparaiso, secretary.

The first speaker of the afternoon was Kelly Wise, Biology Club, New Castle High School, who reported on "A Bird Breeding Population Study." Slides were shown to illustrate the areas which his study included and the nests found in each section.

A "Demonstration on the Processes Used in Photography" was pre-

sented by members of the Sullivan High School Camera Club. Judith Shepherd, Jim LaFollette, Jim Pirtle, and Bevra Boyll showed the various steps in the development of a photograph.

Next on the program was a "Bacteria Study in Vanilla and Chocolate Ice Cream," by David Eads, Science Club, Thomas Carr Howe High School, Indianapolis. Through experiments it had been found that bacteria multiplied more rapidly in chocolate than in vanilla ice cream.

A paper on "Taxidermy," prepared by Robert Petty, also of the Thomas Carr Howe High School Science Club, was presented. The principles of preparing skins for animal mounts were discussed.

Russell Noyes, Science Club, University High School, Bloomington, explained the "Food Habits of Indiana Small Fish." He described the method of determining the approximate food intake of the fish.

Professor Howard H. Michaud, State Sponsor, reported on the progress of the Junior Academy. He announced the names of the students selected by the Junior Academy Council for the titles of "best boy" and "best girl." The title of "best boy" was awarded to Watson Laetsch, Science Club, Thomas Carr Howe High School, Indianapolis, and Joan Freeman, Science Club, Mishawaka High School, was named "best girl." A new system of voting for election of officers was suggested by Professor Michaud. If the plan is approved by the council, two delegates from each high school represented will conduct the election of officers. The national and state science talent search was mentioned. This annual competition for finding science talented seniors in the high schools is sponsored jointly by Science Clubs of America, the Junior Academy of Science, and the Indianapolis Times.

Following these announcements, a demonstration was presented by students of the Science Club, Centennial School, Lafayette. The scientific principles involved in toys were illustrated with a number of interesting examples. This club is the only elementary science club in the Junior Academy.

The program was concluded with a motion picture, "The Fight Against Cancer," furnished by the Indiana Cancer Society.

Approximately two hundred club members, sponsors, and guests attended the excellent meeting at Hanover.

The meeting was adjourned at 4:15 p.m. by president Tom Moon.

EXHIBITS

The exhibits were installed Saturday morning. An attractive display of exhibits was presented, in spite of the great distance many clubs had to travel. Twenty-five science projects were shown by the following clubs:

National Scientific Honor Society, Bloomington High School, Bloomington, Harold Stewart, Sponsor.

Junior Academy, Chemistry Club, Central High School, South Bend, F. S. Sanford, Sponsor.

Science Club, Morton Junior High School, Hammond, Faye E. Moorman, Sponsor.

Biology Club, New Castle High School, New Castle, Robert Rinehart, Sponsor.

Science Club, Thomas Carr Howe High School, Indianapolis, Jerry Motley, Sponsor.

Science Club, University High School, Bloomington, Jack Munsee, and Prevo L. Whitaker, Sponsors.

Biology Club, Lew Wallace High School, Gary, Mrs. Helen McKenzie, Sponsor.

INDIANA JUNIOR ACADEMY OF SCIENCE CLUBS

Name and School	Date Organized	Sponsor
Anderson		
Science	1936	B. B. Horton
Attica		
Sci-Math	1949	J. Claude Daugherty
Bloomington		
National Scientific Honor Society, Bloomington H.S.	1931	Harold Stewart
Science, University H.S.	1938	P. L. Whitaker Jack Munsee
Crawfordsville		
Up-N-Atom	1950	David Wells
Elkhart		
Junior Academy	1940	Evelyn Wagoner
Fort Wayne		
Phy Chem, Elmhurst H.S.	1935	Ruth Wimmer
Nature, Central High School	1940	Iva Spangler
Nature, North Side High School	1936	Vesta Thompson C. H. Ott
Gary		
Beaker Breakers, Edison H.S.	1947	Mrs. Martha B. Connor
Future Scientists of America Tolleston School	1949	Juanita Joice
Biology, Lew Wallace H.S.	1935	Lola Lemon
Klub Kem Klub, Lew Wallace H.S.	1941	Mrs. Helen McKenzie
Biology, William A. Wirt H.S.	1945	Mrs. Frances Huddleston
Hammond		
Science, Morton Jr. H.S.	1949	Faye E. Moorman
Huntingburg		
Science	1949	Wilmer K. Pellett
Indianapolis		
Science, Thomas Carr Howe H.S.	1949	Jerry Motley
Chemistry, Shortridge H.S.	1931	William Johnson

Nature, Shortridge H.S.	1947	Mrs. Henrietta A. Parker
Nature, Technical H.S.	1932	Howard L. Cook
Science, Washington H.S.	1937	Estil Van Dorn
Lafayette		
Science, Centennial School	1948	Henrietta S. Ball
Marion		
Science	1936	Keith Stroup
Mishawaka		
Science	1936	Darl F. Wood
New Castle		
Biology	1948	Robert Rinehart
Richmond		
Science, Senior H.S.	1949	Katherine Coulter Elma Eliason
South Bend		
Junior Academy, Central H.S.	1939	
A. Junior Izaak Walton		A. L. Smith
B. Chemistry		F. S. Sanford
Sullivan		
Camera	1939	Ruth Hinkle
Terre Haute		
State Discovery, Laboratory School	1939	Russell McDougal
Valparaiso		
Sciemus	1931	Glenn Fisher

INSTRUCTIONS FOR CONTRIBUTORS

Eligibility

Papers

Indiana Academy of Science members in good standing are eligible to submit papers for publication in the Proceedings. When a paper is signed by two or several authors, all must be members in good standing. Preferably, eligibility should be established before submitting the paper, as such papers are given priority. In any case, all authors must be certified by the Treasurer for payment of dues and old reprint bills at the time of the deadline (see below). Papers reaching the editor after the deadline are ineligible. All papers must be accompanied by an abstract in the form specified below, marked "for the editor".

Abstracts

If the Divisional Chairman puts a paper on his program for the Fall Meeting, the abstract will be printed in the Proceedings regardless of the author's membership status, unless the full paper is published.

Time and procedure for Submitting Abstracts: One typed **original** of each abstract, marked "for the editor" may be submitted to the Divisional Chairman before the meeting or the author may mail it direct to the editor. This should be ready for publication with a minimum of editing, i.e., in the standard abstract form (see a Proceedings abstract) and double spaced; it should not include directions to the chairman regarding time, lantern, etc. The latter information may be added to a copy marked "for the Divisional Chairman" and sent to him. The editor cannot accept carbon copies of abstracts or papers. The length of an abstract should not exceed 200 words. Items A, B, C, E, F, and O apply generally to abstracts as well as papers.

Deadline at Editorial Office

Whether sent *via* the Divisional Chairman as prescribed, or directly, all material for the Proceedings must reach the editor within 20 days following the Fall Meeting.

Preparation of Manuscripts

A. **Refer to Volume 60 of the Proceedings for the accepted style of abstracts and papers, and follow this, especially in literature citations, headings, and footnotes.**

B. Type on 11 x 8½ inch bond paper with a new ribbon, leaving ample margins. **Double-space everything,** including title, author's names and institutions, footnotes, quotations, legends and literature list. The original will become the printer's copy; if it must be retyped it will be sent back to the author for this.

C. Footnotes should be kept to an absolute minimum. Necessary footnotes should be numbered consecutively throughout; asterisks are not used. Acknowledgments may be placed only in the introduction or in a footnote. If your abstract must cite literature, use a footnote.

D. LITERATURE CITATIONS in a paper should not occur in footnotes, but in an **alphabetized** list at the end of the paper, **headed "Literature Cited".** The highly abbreviated form used by chemists has **not** been adopted for the Proceedings. Follow this model:

7. DOE, J. B., and R. C. ROE. 1949. New light from old radioactive carbon. Jour. Am. Biological Soc. **34**:273-305.

E. Only initial letters of the words in titles, headings, and table headings should be capitalized.

F. Do not underline anything except scientific names, in headings or elsewhere.

G. All literature listed, and all tables and illustrations should be **referred to** in the text.

H. Tables, which are very expensive to print, should be reduced to a minimum. Avoid small tables scattered through the text. Each table should be typed on a separate letter-size sheet.

I. New authors, especially, are reminded that a scientific paper should summarize the work, not recapitulate it. It must be very much more concise than a university thesis, avoiding all unnecessary material, especially long tables and lists of little interest except to the author.

J. Major professors are urged to **review** all papers by their graduate students, for both form and content, before they are sent in for publication. Of those based upon university theses, manuscripts carrying a pencilled O. K. and signature by the professor will be given preference over those without such indication of review.

K. Photographs should be printed on glossy paper, and have good contrast. It is best to mount them trimmed to fit tightly together at the edges, in groups on stiff cardboard with rubber cement. Proportion the group for a full page of the Proceedings, or use the full width of the page (4⅛″) and any part of the page's height. Do not mix line drawings and photographs in the same group. Legends should be on a separate letter-size sheet, numbered to correspond.

L. The originals for line drawings need be no more than twice the diameter desired for the printed figure. The lettering should be very carefully done, and of suitable size to allow for the necessary reduction. Do not submit printed maps when the necessary reduction will efface the narrower lines or render some of the lettering hardly legible; such maps should be redrawn and lettered in adequate size letters, omitting unnecessary details. It is suggested that the total of illustrations and tables not exceed 20 per cent of the length of the whole paper.

M. The summary should be complete and clear in itself, and not over 4 percent of the length of the paper. For very short papers no summary is necessary.

N. Reprints of papers are paid for by authors, at cost. They are ordered at the time the author returns the corrected galley proof to the editor. Abstracts are not reprinted.

O. The editor needs, at the time he mails out galley in March, **current addresses** for all coauthors of all abstracts and papers. Many former graduate students lose the opportunity to order reprints when mail addressed to them is returned for lack of forwarding addresses. It is suggested that the student's permanent home address be written on the reverse side of that abstract copy marked "for the editor."

Selection of Papers

Every year a few more papers are submitted than can be published with the available funds. Therefore, not all papers received can be included in the Proceedings. Manuscripts prepared concisely, in the style recommended above, will receive first consideration. Authors should not expect to publish very long papers in the Proceedings. Among papers of primarily regional interest, e.g., in certain aspects of botany, zoology, geology, geography, and anthropology, those dealing with Indiana material will be accorded preferance.

The selection of papers for the Proceedings is the responsibility of the Editorial Committee.

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